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FINAL REPORT ON THE ELECTRONIC EVALUATION OF THE ADVANCED DYNAMIC ANTHROPOMORPHIC MANIKIN (ADAM) IN HIGH TEMPERATURE ENVIRONMENTS

Eric K. Spittle
Roy R. Rasmussen
Ints Kaleps

CREW SYSTEMS DIRECTORATE
BIODYNAMICS AND BIOCOMMUNICATIONS DIVISION

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FOR THE COMMANDER

JAMES W. BRINKLEY, SES
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6. AUTHOR(S)
Eric K. Spittle, 1Lt, USAF
Roy R. Rasmussen
Ints Kaleps, PhD

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13. ABSTRACT *(Maximum 200 words)*
This report documents the results of the high ambient temperature chamber tests performed on the Advanced Dynamic Anthropomorphic Manikin (ADAM). These tests were conducted as supplementary tests to a program that was conducted in 1987 when the ADAM was exposed to high and low temperatures and high and low humidities. From the results of the 987 tests, it was concluded that the ADAM may have difficulty operating in high ambient temperatures above 160°F. The tests described in this report were used to determine a safe operational temperature threshold for the ADAM and to determine probable causes of manikin shutdown at temperatures above this range. The safe viscera operational temperature threshold was determined to be 180°F. This correlates to a safe ambient operational temperature threshold of 130°F with a worst case manikin set up. To determine when the ADAM shut down above this temperature, manikin internal load cells, potentiometers, and accelerometers were excited and monitored external to the manikin. Additionally, circuit board voltages were externally monitored to determine when and which circuit boards shut down during a test. Finally, data were collected from the ADAM periodically to monitor the operational status of the manikin and any effect the temperatures were

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having on the sensors and data acquisition system of the manikin. The temperature profiles selected were representative of the operational temperatures the ADAM will experience in the F-16 cockpit mockup on the Multi-Axis Seat Ejection (MASE) sled at Holloman AFB, NM, where the ADAM will be used for Air Force ejection tests in the near future. A secondary objective of the test program was to determine whether the MASE sled cockpit would have to be modified to add conditioned air to keep the ambient temperature of the cockpit below the safe operational temperature threshold. In normal operation the MASE sled cockpit does not reach a temperature of 130°F and, based on these tests, it was concluded that no modifications to the MASE sled would be required.

PREFACE

The investigations described in this report were conducted under Air Force Contract F33615-85-C-0535, "Advanced Dynamic Anthropomorphic Manikin". The investigations were conducted by the Biomechanics Branch, Biodynamics and Bioengineering Division, Armstrong Laboratory (AL/BBM) and supported by Systems Research Laboratories, Inc. (SRL), 2800 Indian Ripple Road, Dayton, Ohio. The tests were conducted at the Wright Laboratory, Sensor and Evaluation Branch's high temperature test chamber (WL/AARF), Wright-Patterson AFB, Ohio.

Lt Eric K. Spittle was the test conductor and Air Force mechanical engineer. Aileen M. Bartol was the SRL mechanical engineer. James R. Bolton was the SRL electrical engineer and Greg A. Thompson was the SRL technician. Mr Mike Fabian was the Wright Laboratory test chamber operator.

Funding for this project was provided by the Crew Escape Technologies Branch (CREST) of the Human Systems Division (HSD/YAH-CREST), Wright-Patterson AFB, Ohio.

Special thanks are given to Aileen, Jim, and Greg of SRL and Mike of Wright Laboratory for all of their hard work and resourcefulness on this project. Special thanks are also given to the CREST office whose funds made this project possible.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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INTRODUCTION

This report describes the high temperature, high humidity tests that were conducted on the Advanced Dynamic Anthropomorphic Manikin[1] (ADAM) at the Wright Laboratory, Sensor and Evaluation Branch's (WL/AARF) high temperature test chamber from 4 April - 8 May 1990. These tests were conducted as supplementary tests to a high and low temperature, high and low humidity test program conducted in 1987[2]. The results of the 1987 program concluded that the ADAM had no operational difficulty with respect to humidity. Humidities in the 1987 test program ranged from a high of 98% to a low of 14%. The 1987 tests also proved that the ADAM had no difficulty operating in temperatures down to 32°F. The tests did show that at high ambient temperatures the ADAM may shut down. Because a precise safe operational temperature threshold and specific reason why the manikin shut down were not determined, the additional tests described in this report were conducted.

The first objective of these tests was to determine a safe operational temperature threshold. This was accomplished by subjecting the ADAM manikin to various temperature profiles in several configurations. Four different temperature profiles were created to reflect the temperature environment that the ADAM may experience during ejection tests at Holloman AFB, NM. These profiles also helped to achieve the second objective, which was to determine if the Multi-Axis Seat Ejection (MASE) sled needs to be fitted with a conditioned air system to keep the ADAM cool enough during preparation for ejection tests to ensure reliability.

For each profile a total of four tests were conducted. Two tests were conducted with different outer clothing materials and the manikin in "stand-by" mode, analog circuits off. Another two tests were conducted with different outer clothing materials and the manikin fully powered, all circuits on. This testing configuration was run for each profile, resulting in a total of 16 tests. The temperature profiles were conducted in the same sequence as they appear in Figures 1-4.

Given the temperature range expected in the MASE sled cockpit, the ADAM manikin should function without the aid of conditioned air. However, if an ejection test is delayed and the ADAM is in the cockpit and fully powered, the internal viscera temperature should be monitored. If the viscera temperature exceeds 180°F the manikin should be put in "stand-by" mode until the time of the test. The safe operational internal viscera temperature threshold was determined to be 180°F. This temperature, though, does not easily correlate to a precise ambient temperature. A safe operational ambient temperature threshold is a function of the temperature profile, thermal gradients and soaking time, manikin power status, and outer clothing material. The tests showed that the manikin could operate in the entire range of

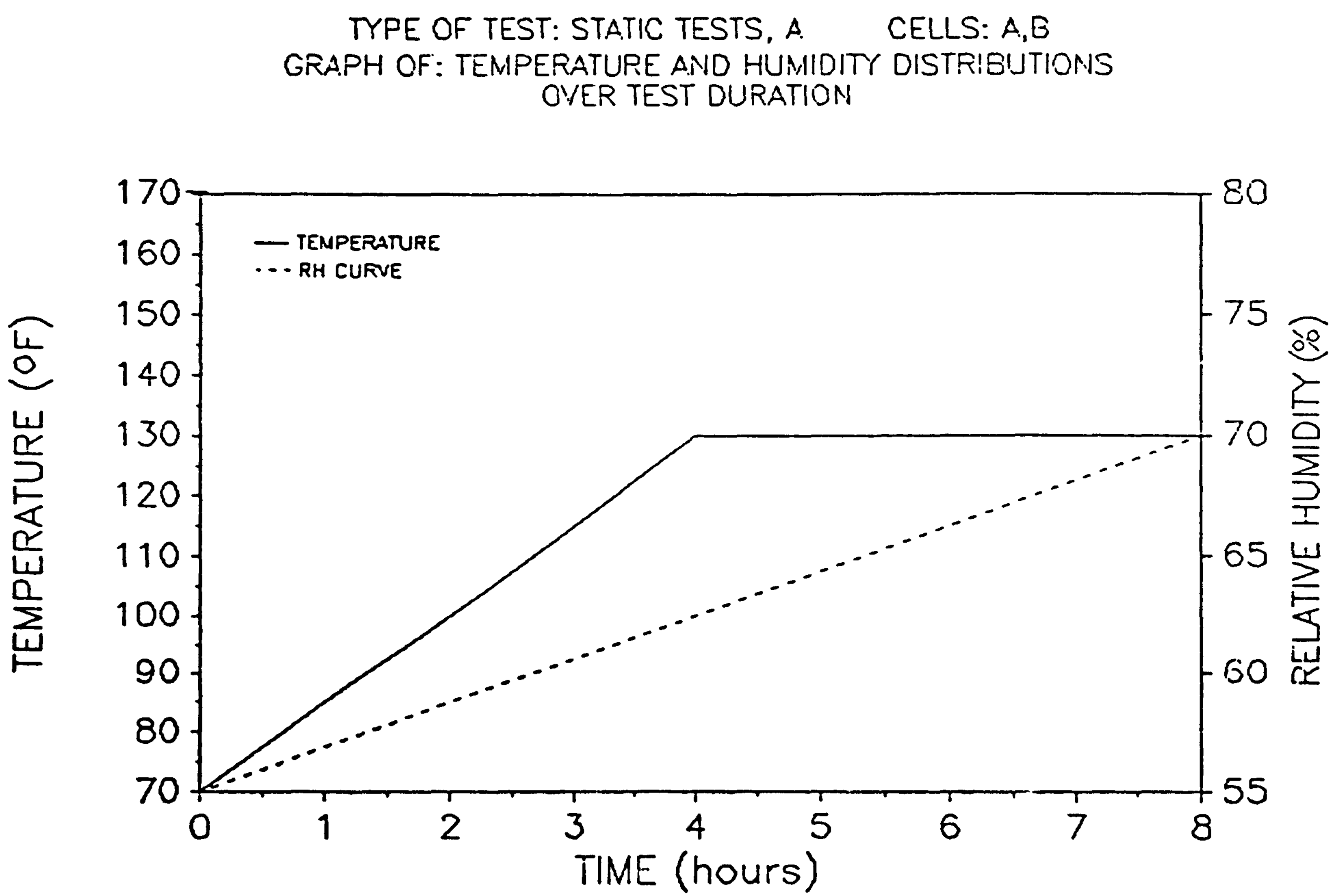


Figure 1 - Static Tests, A

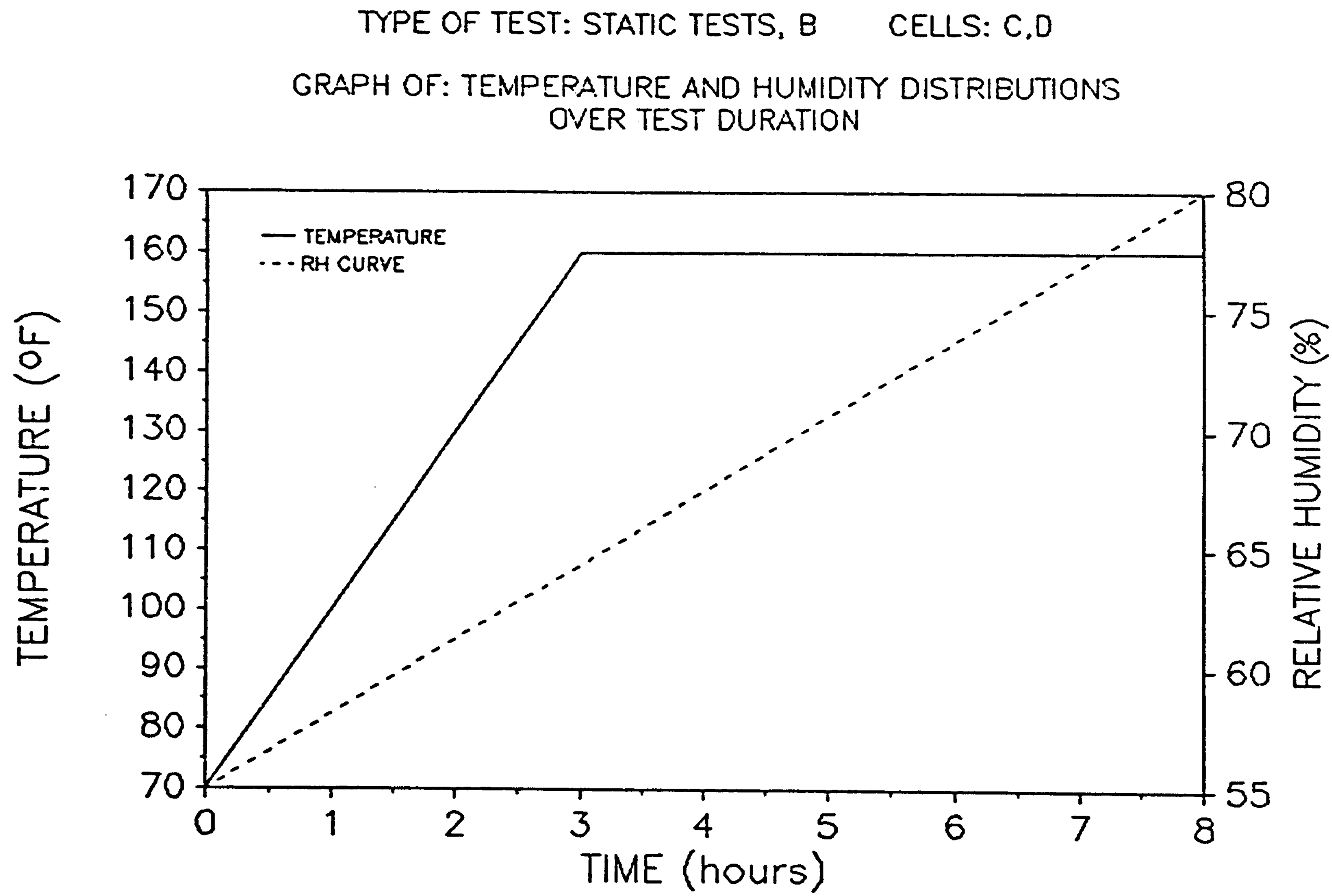


Figure 2 - Static Tests, B

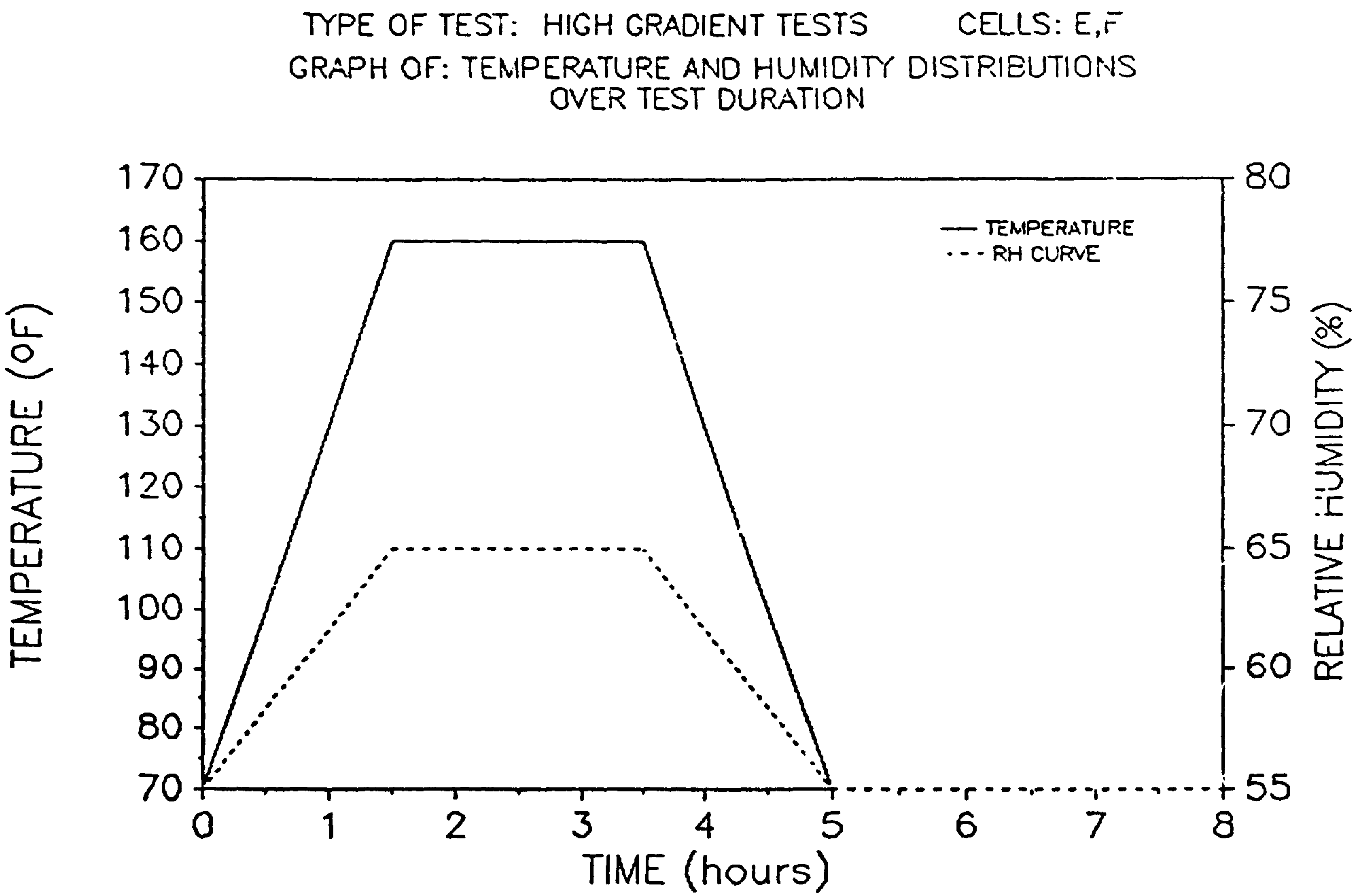


Figure 3 - High Gradient Tests

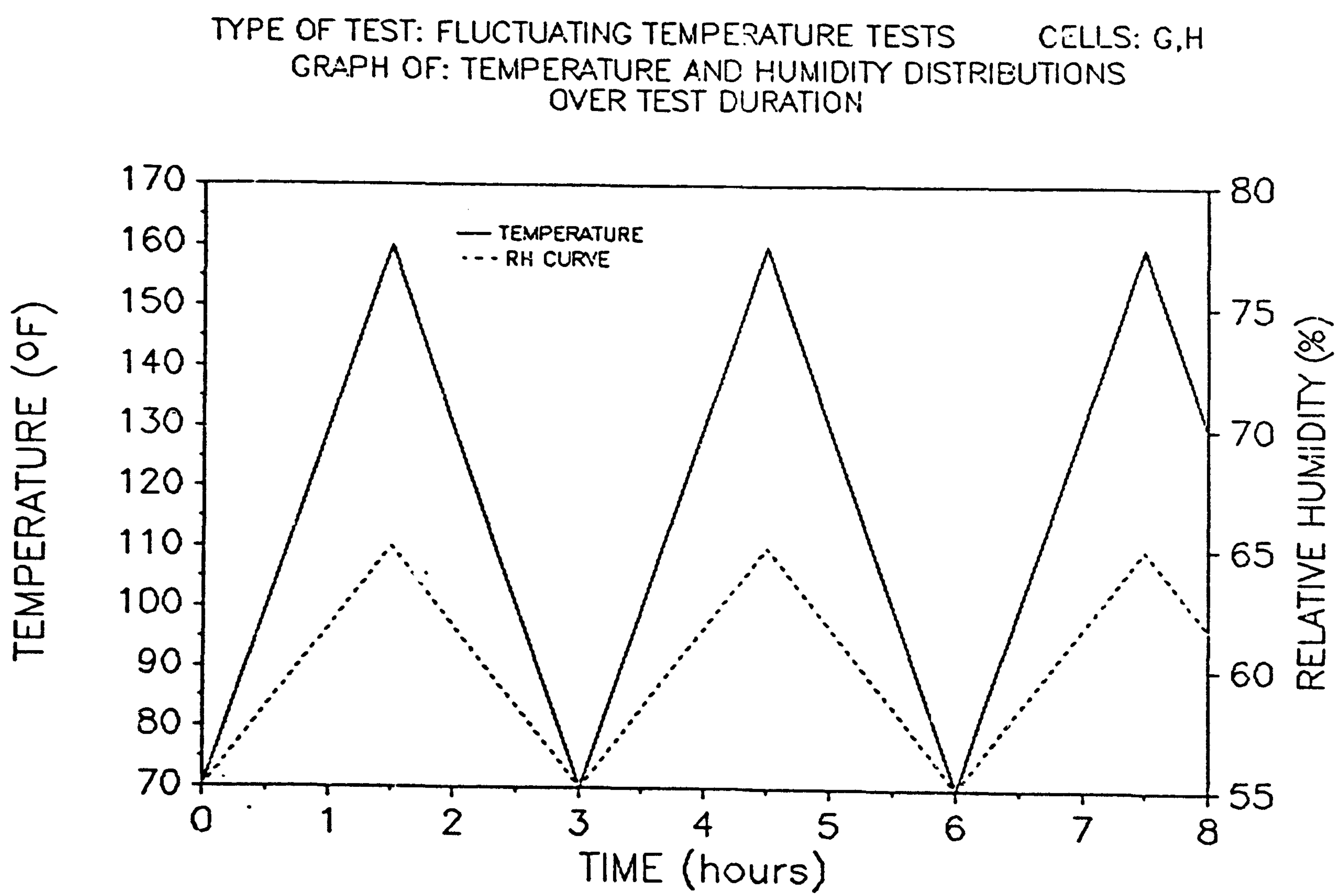


Figure 4 - Fluctuating Temperature Tests

ambient temperatures under certain conditions. A safe operational ambient temperature threshold including all cases was determined to be 130°F.

Section two of this report describes the background of these tests, test objectives, thermal profiles, and a general test set-up. Section three describes the viscera box, viscera temperature, and an analysis of the individual test characteristics on the viscera temperature. Section four defines the safe ambient and viscera operational temperature thresholds. Section five describes how the ADAM shut down during certain tests and describes the source of the shut down. Section six describes the effect of temperature on the position potentiometers, accelerometers, and load cells monitored during the tests, as well as the data acquisition system of the ADAM. Finally, section seven provides some concluding remarks.

TEST DESCRIPTION

Background

The Advanced Dynamic Anthropomorphic Manikin (ADAM) was subjected to four different thermal profiles in a high temperature test chamber to determine the electronic degradation that high temperatures would have on the manikin's operating system. Due to the results of thermal tests conducted on a prototype ADAM in 1987, it was apparent that the manikin might not always operate properly in ambient environments above 140°F, but neither a specific internal temperature nor a cause of the manikin shut down was determined. Because of the results of the tests conducted in 1987 and the planned use of ADAM in the Multi-Axis Seat Ejection (MASE) sled at Holloman AFB, NM, where the ambient ground temperature can be over 100°F in the Summer, the tests discussed in this report were conducted.

Objectives

The primary objective was to determine a safe operational temperature threshold for the manikin. In addition it was considered significant to isolate the possible cause or causes of manikin shut down when the internal temperature went too high. The secondary objective of the test program was to determine whether the MASE sled would have to provide conditioned air to the cockpit to keep ADAM below the determined safe operational temperature threshold.

Thermal Profiles

In order to find an answer to the second objective the thermal profiles used for the tests were created to simulate possible thermal scenarios the ADAM might encounter at Holloman AFB NM. The same profiles were also used to satisfy the first testing objective. Figures 1-4 show the thermal profiles the ADAM was subjected to in the test chamber. All tests began by soaking the test chamber at 70°F and 55% humidity for 15-30 minutes, after which the test profile was started. Each profile was entered into two computers that controlled the Thermotron unit.
The first computer provided the dry bulb temperature data to control the Thermotron and matched the profile in each of the Figures 1-4. The second computer provided wet bulb temperature data to the Thermotron. Figure 5 shows a test's Thermotron wet and dry bulb thermocouple and humidity sensor data. These two thermocouples and a humidity sensor were located inside the chamber immediately in front of the blower unit. Figure 6 shows

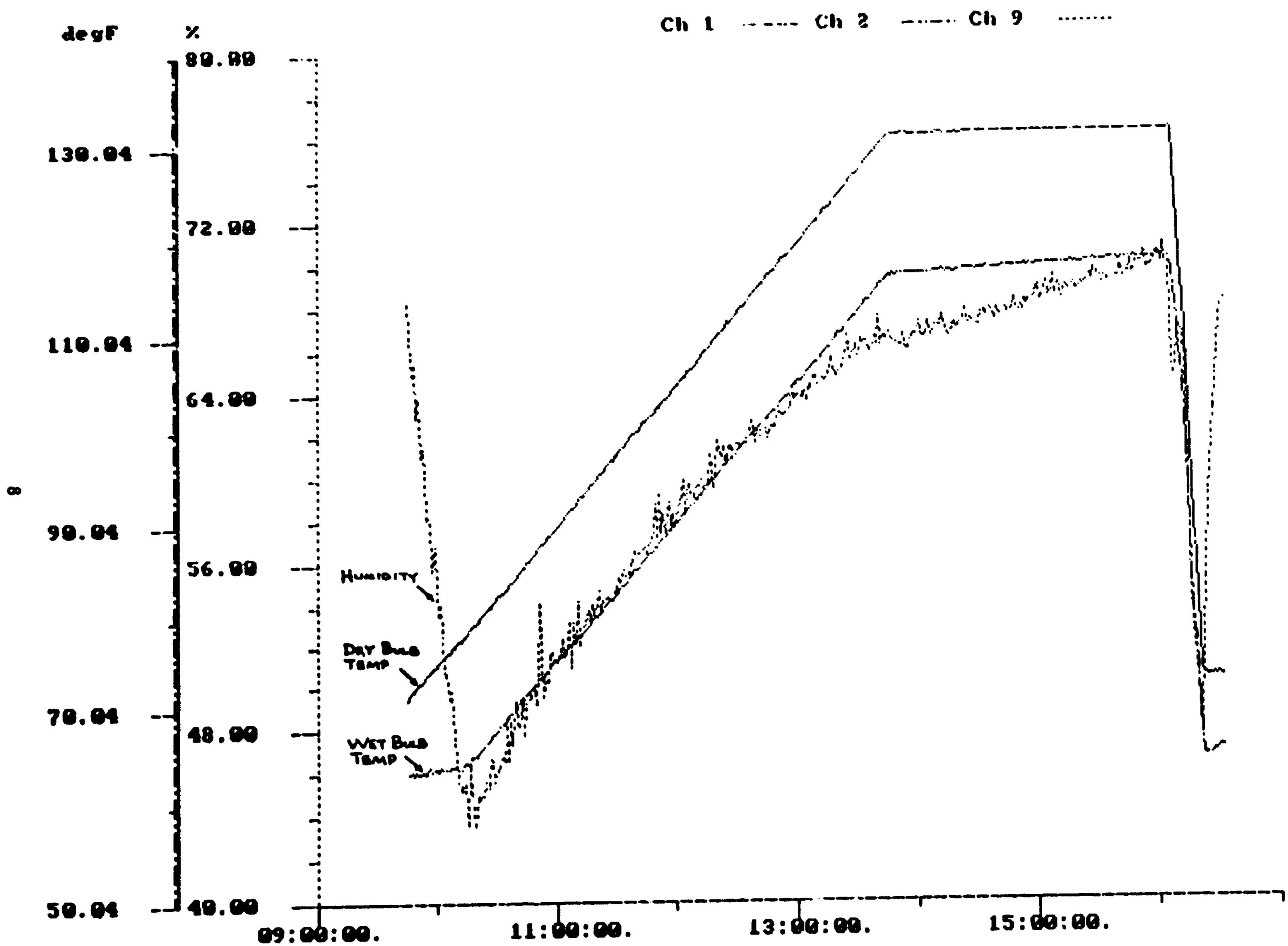


Figure 5 - Thermotron Wet & Dry Bulb Temperature and Humidity

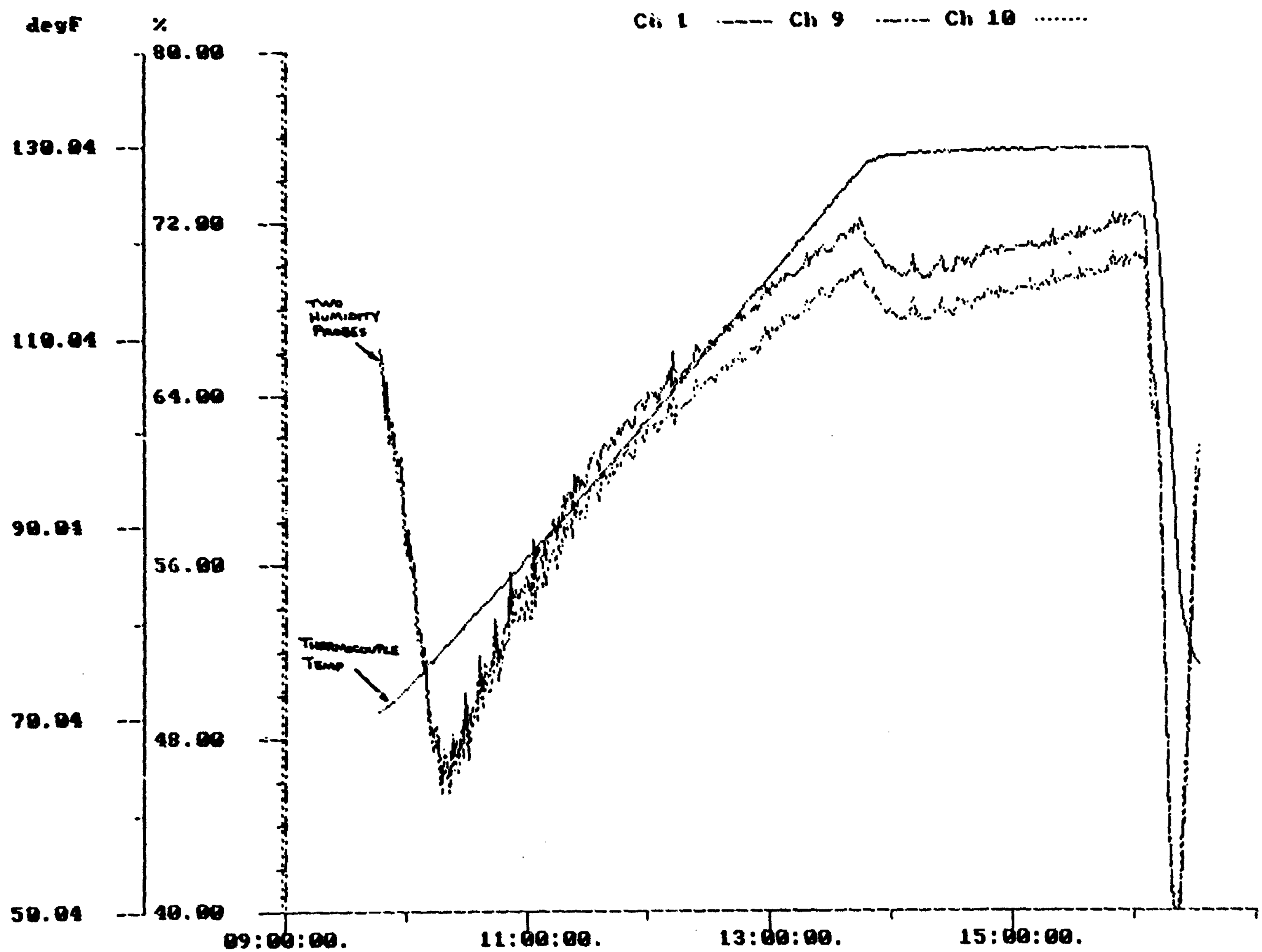


Figure 6 - ADAM Grid Dry Bulb Temperature and Humidity

the same data from the thermocouple and humidity sensors where ADAM was sitting, ten feet away from the blower.

Test Set-up

The chamber itself was 12 feet square with the blower centered along the back wall. ADAM was placed near the side wall closest to the instrumentation room, ten feet from the blower and two feet from the side wall. ADAM was originally to be positioned near the center of the chamber but preliminary test results showed that the blower was able to provide a uniform temperature distribution for the entire room. In addition, some of the instrumentation cables tnat were connected to ADAM would have required lengthening to position him farther from the side wall.

In the 1987 thermal tests ADAM was subjected to humidities ranging from 14-98%. ADAM showed no adverse effects from the humidity levels in those tests. Therefore, when programming the thermal profiles into the computers it was recognized that the critical factor in these tests was temperature degradation on the instrumentation system. Humidity was given a second priority. Because of this, the humidity plots, like those of Figures 5 and 6, do not exactly match the profile expected in Figures 1-4. This was not considered a detriment to these tests because the humidity levels were only sacrificed to the point that the temperature would not deviate from the specified profile.

A total of 16 tests were performed, four with each profile. Figure 7 illustrates the test schedule and the dates the actual tests were performed. Four unique tests were performed with each temperature profile before continuing with the next profile. Tables 1-4 show how each of the four tests were unique to a profile. Each test was designed to be slightly more difficult by increasing the internal viscera temperature for each subsequent test.

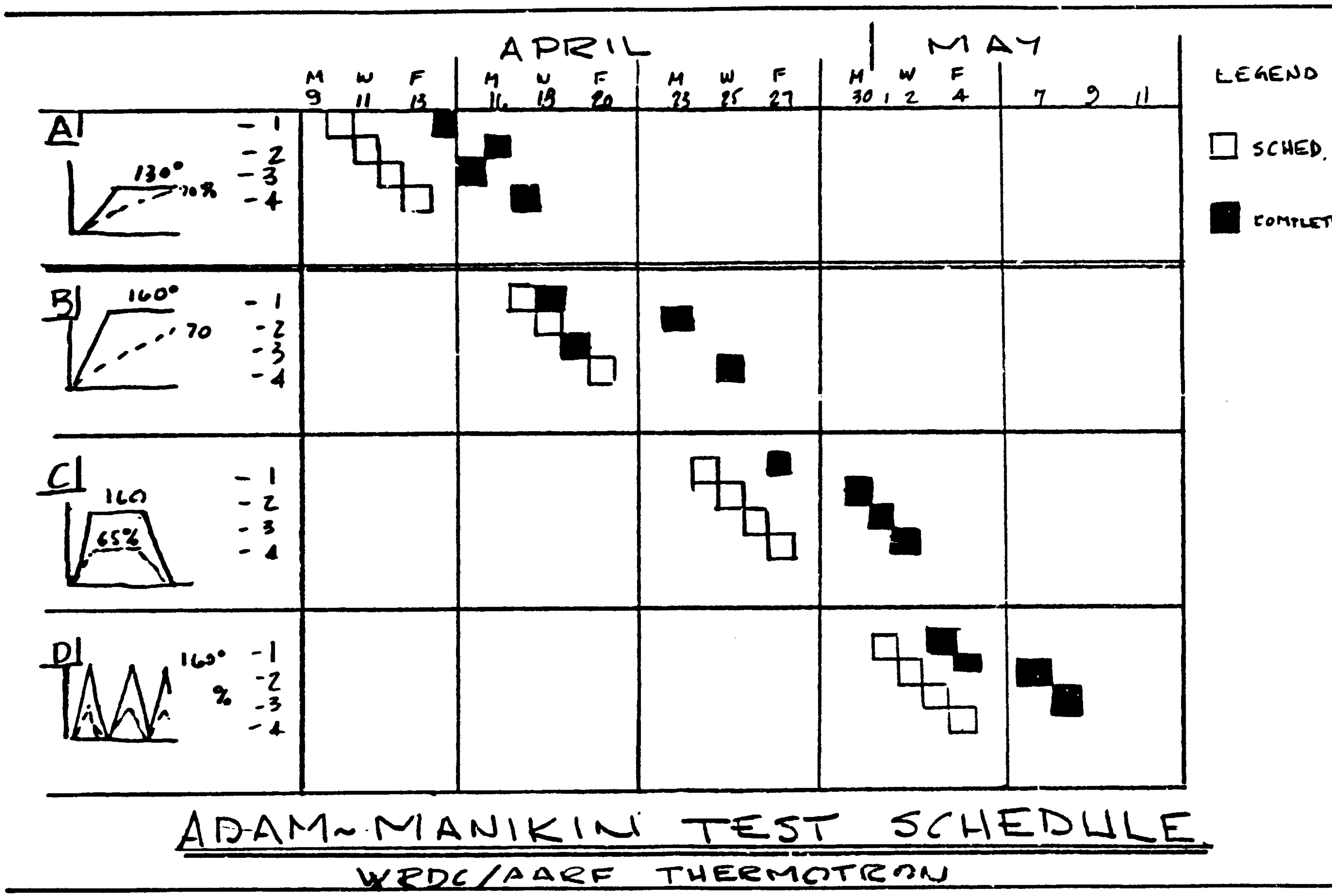


Figure 1 - Test Schedule Matrix

TYPE OF TEST: STATIC TESTS, A

REMARKS: To fulfill CREST requirements. Start at ambient room temp and humidity. Use maximum anticipated gradients (Temp primary, RH secondary) to achieve maximum anticipated temp and RH for Holloman AFB. Continue at final conditions for at least 3 hours.

Test Cell	#	Initial conditions Temp (deg F)	Initial conditions RH (%)	Temp Grad (deg F/Hr)	RH Grad (%/Hr)	Final Temp (deg F)	Final RH (%)	ADAM Status
A	1	70	55	15	2	130	70	Standby
A	2	Repeatability of test 1 - Flight Suit						
B	1	70	55	15	2	130	70	DECOM Dump
B	2	Repeatability of test 1 - Both Suits						

Table 1. Static Tests, A

TYPE OF TEST: STATIC TESTS, B

REMARKS: To test contractual requirements. Start at ambient room temp and humidity. Use large gradients to achieve high temperature and humidity (Temp primary, RH secondary). Continue at final conditions until failure or reasonable time.

Test Cell	#	Initial conditions Temp (deg F)	Initial conditions RH (%)	Temp Grad (deg F/Hr)	RH Grad (%/Hr)	Final Temp (deg F)	Final RH (%)	ADAM Status
C	1	70	55	30	3	160	80	Standby
C	2	Repeatability of test 1 - Lycra Suit						
D	1	70	55	30	3	160	80	DECOM Dump
D	2	Repeatability of test 1 - Both Suits						

Table 2. Static Tests, B

TYPE OF TEST: HIGH GRADIENT TESTS

REMARKS: To test the ADAM's ability to function properly in a highly accelerating/decelerating temperature environment. The test matrix shows the first half of the test. After holding the final temperature and RH for 2 hours, cool the chamber to ambient conditions using the same gradients.

Test Cell	#	Initial conditions Temp (deg F)	Initial conditions RH (%)	Temp Grad (deg F/Hr)	RH Grad (%/Hr)	Final Temp (deg F)	Final RH (%)	ADAM Status
E	1	70	55	60	5	160	65	Standby
E	2	Repeatability of test 1 - Flight Suit						
F	1	70	55	60	5	160	65	DECOM Dump
F	2	Repeatability of test 1 - Both Suits						

Table 3. High Gradient Tests

TYPE OF TEST: FLUCTUATING TEMPERATURE TESTS

REMARKS: To test the ability of the ADAM's to function properly in a continuously fluctuating temperature environment. As soon as the final conditions are met, reverse the gradients to cool the chamber and complete the cycle. A minimum of 2 complete cycles should be performed.

Test Cell	#	Initial conditions Temp (deg F)	Initial conditions RH (%)	Temp Grad (deg F/Hr)	RH Grad (%/Hr)	Final Temp (deg F)	Final RH (%)	ADAM Status
G	1	70	55	60	5	160	65	Standby
G	2	Repeatability of test 1 - Lycra Suit						
H	1	70	55	60	5	160	65	DECOM Dump
H	2	Repeatability of test 1 - Both Suits						

Table 4. Fluctuating Temperature Tests

VISCERA CHARACTERISTICS

Viscera Heat Dissipation

All of the ADAM electronic circuitry is contained inside the enclosed aluminum case known as the viscera. It is enclosed to provide strength to the box and to prevent contaminants such as dirt or sand from entering the circuit card array. The main drawback of the enclosed viscera box is the lack of ventilation for internally generated heat. A few small openings around the wire bundles that enter and exit the box provide minimal convective heat dissipation. The ADAM always has a vinyl flesh covering over its entire body that prevents substantial air flow around the viscera box. The air between the flesh covering and the viscera is nearly static, therefore any heat that the viscera dissipates must come from conduction. The aluminum box acts as a good heat sink. Throughout the test series thermocouples were placed on various parts of the manikin to record temperature measurements for comparison to the ambient and viscera temperatures. The outside and top of the viscera box would heat at times to within 10°F of the inside viscera temperature, well above the ambient chamber temperature, see Figure 8.

ADAM Power Settings

Manikin shut down is a function of the temperature gradient and soak time, manikin power status, and outer clothing material. To determine which factors effect manikin shut down and to what extent, each profile was run four times with each test being unique. Refer again to Tables 1-4 and notice that each profile contains two test cells of two tests each. Each test cell refers to a specific power setting on the manikin. There are three possible power settings with the ADAM. The first is no power, when the manikin is off. No data acquisition capability is available without powering the ADAM. Because this does not generate any internal viscera heat it was excluded from testing.

The second power setting is "stand-by". With this setting the manikin is fully powered, diagnostics checked, and using the handheld terminal the analog circuits are turned off while keeping the digital circuits on. This provides some heating of the viscera, but because the analog to digital (A/D) converters and the other analog circuits are off, most of the heat generating circuits are off. Again data collection is not possible with the manikin in the stand-by mode, but it does serve two very useful purposes. First, for a remote test, like those that will be conducted at Holloman AFB NM, the ADAM will be run using its internal lithium batteries. Due to the fact that the test may be delayed for several hours with the manikin on full power the batteries may be drained and have to be replaced,

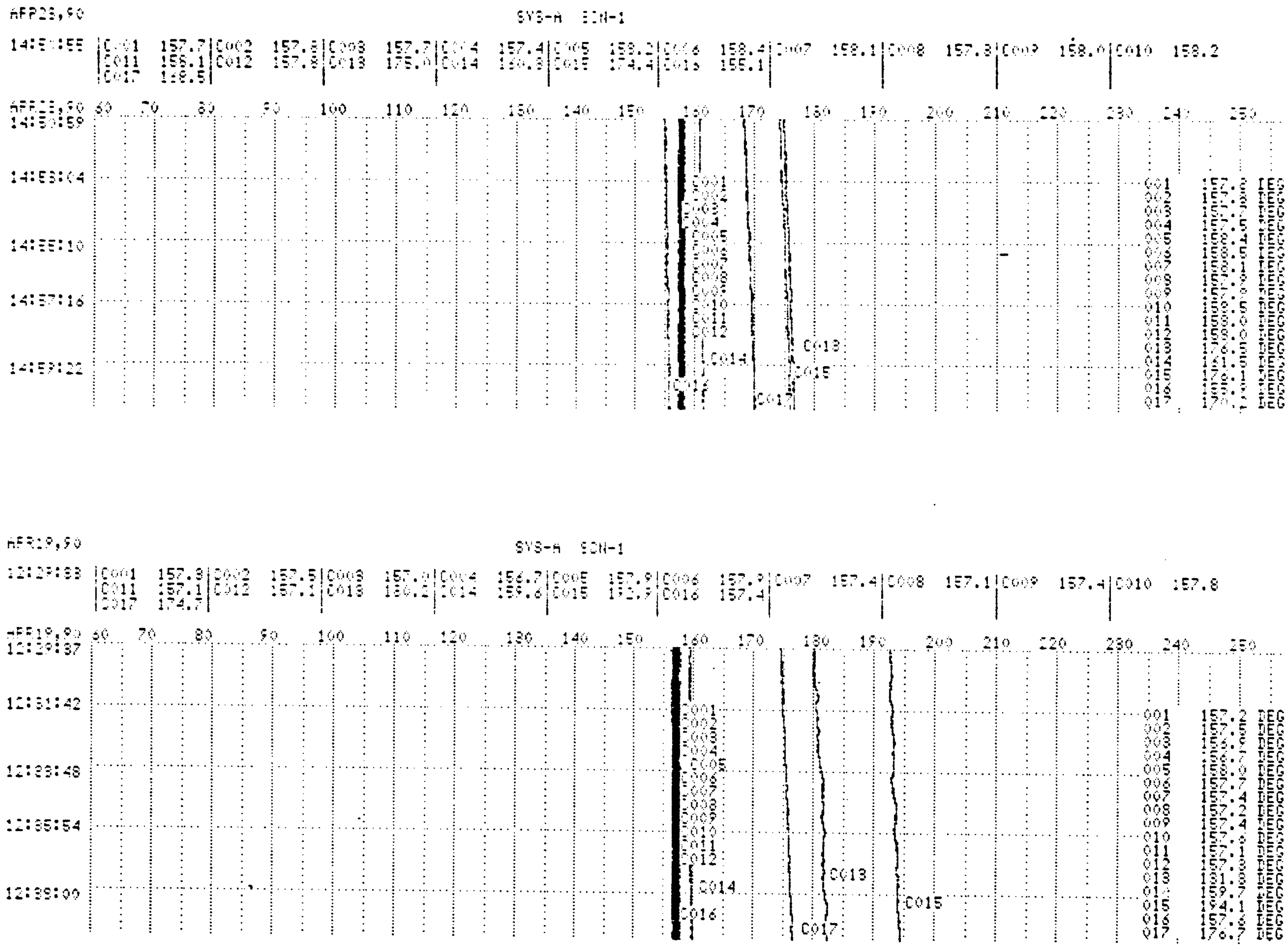


Figure 8 - Acurex Plots of ADAM Grid Thermocouples

resulting in having to defer the test. The lithium battery configuration in ADAM can only be used for one test because there is no way to check the life of the battery so turning the manikin off is not a solution. However using the stand-by mode, digital communication can continue while the energy draining analog circuits are off. The second purpose is that the stand-by mode also creates much less heat because the analog circuits are off. The third power setting is full power, all circuits on. With all of the circuits on in the viscera almost 40 watts are dissipated.

Test Characteristics That Affect Viscera Temperature

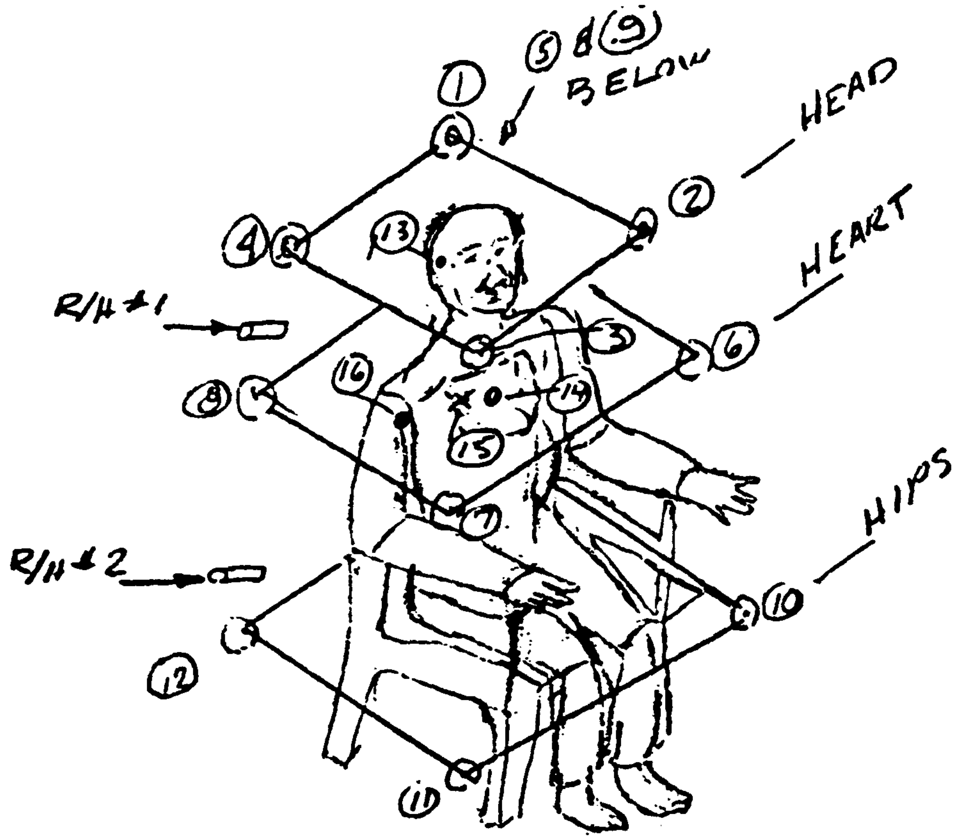
For each test cell, which represents either the stand-by or full power setting, two different tests were designed, varying the outer clothing material. For the first test in every test cell ADAM was only covered with its own vinyl flesh coverings, no outer clothing materials. The second test of each stand-by test cell alternated either a cotton flight suit or stretch lycra suit designed for ejection tests to prevent sand and dirt from contaminating the electronics or damaging the highly biofidelic joints. The second test of each full power test cell had ADAM wearing the lycra suit and flight suit over top. This is the most likely configuration for ejection testing.

Viscera Temperature

Each test A1, A2, B1, B2 was designed to step increase the internal viscera temperature. Test results showed that one covering of clothing material, either the lycra or the flight suit, increased the internal viscera temperature 8-12°F, depending on the temperature profile and test time elapsed. Both suits provided about the same thermal insulation to the manikin. For the full power tests, when both suits were worn together, the internal viscera temperature increased 12-17°F.
From these results it is apparent that with different power settings and different outer garments and an ambient temperature profile between 130-160°F the ADAM may work fine for some of these tests, but shut down for others. With the four tests run in the first profile, see Figure 1, ADAM had no difficulty passing the first three. In fact, the internal temperature at the end of the third test, at full power, measured by the internal probe, which is part of the ADAM instrumentation, measured 242°F. But in the fourth test, when ADAM was fully powered and wearing both suits, it shut down after the temperature profile was met, but before the end of the test. ADAM was then put on stand-by and data was later collected, but not until the viscera temperature was below 240°F. A detailed test by test description taken from the test log is included in the Appendix.

The temperature probe that was mentioned in the preceding paragraph is part of the ADAM instrumentation. The probe is located in what has been determined to be the hottest part of the viscera box, just above a set of analog to digital converters. Therefore this probe will measure very hot temperatures when the manikin is fully powered, but when ADAM is on stand-by the A/D converters are not on and generating heat. Because the viscera is a closed box, there is very little air flow. The air rises as it is heated, but very little is able to escape. As the viscera box heats and heated air already occupies the top of the box, the air stagnates, creating pockets of hotter air localized around the circuits that are creating the heat. When ADAM is on stand-by another part of the viscera is the hottest and the A/D circuits now lie as a "cooler" zone. Therefore the temperature of the internal probe may not always represent the hottest part of the viscera at that time.

To get a better feel for the temperature gradients inside the viscera, two thermocouples were placed inside and continuously monitored throughout a test. As the test description in the Appendix shows, these thermocouples were located on opposite corners at the top of the viscera to determine temperature gradients present inside the box. Because the thermocouples were a copper and constantine twisted pair with an open contact surface, care was taken not to contact any operating circuit. Because of this, the thermocouples were only placed a few inches inside the viscera box. Figure 9 displays the placement of the 17 thermocouples in, on, and around ADAM. From the Acurex plots shown in Figures 10-11 it is apparent that there is a temperature gradient inside the viscera. The two thermocouples of concern here are #13 and #15. Thermocouple #13 is located near the top of the viscera on the right side of ADAM as you look at it from the front. Thermocouple #15 is located near the top of the viscera on the left side, which is above the A/D converters. Figures 10-11 show the chamber temperature after the mission profile has been met. Figure 10 shows the temperature measured by thermocouple #15 is about 12°F hotter than that for #13. This figure is taken from test #6, which is a second profile test, Figure 2. This was a full power test and it can be seen that there is a temperature gradient across the top of the box. ADAM's internal temperature probe was measuring 240°F at the A/D converters, so another gradient exists from the top to the bottom of the box. Figure 11 shows thermocouples #13 and #15 at almost the same temperature, indicating very little temperature gradient across the top of the box. Also note that the temperature inside the viscera is about 20°F cooler than that shown in Figure 10. Figure 11 is taken from test #7, also profile #2, but a stand-by test. No ADAM internal temperature probe data is available for stand-by tests as the temperature probe is an analog circuit, which is off. The temperature data from ADAM is slightly inflated for stand-by tests, as the manikin is fully powered for a minute to stabilize the system and then data collected. This only affects the temperature probe data, because as Figure 12



MANIKIN ADAM
AARF INSTRUMENTATION

⊙ - AIR
• - SURFACE - EXT
x - SURFACE - INT.

CH.	LOCATION	T/C s
1	HEAD -	LT AFT
2	"	LT. FWD
3	"	RT. FWD
4	"	RT AFT
5	HEART -	LT AFT
6	"	LT FWD
7	"	RT FWD
8	"	RT AFT
9	HIPS -	LT AFT
10	"	LT FWD
11	"	RT. FWD
12	"	RT AFT
13	HEAD	surface
14	HEART skin surface	surface
15	VISCERA BOX RT UPPER ARM	INT.
16		surface
17	VISCERA SURFACE	SURFACE

Starting 4/18 TEST 8.05 #13 moved to upper left arm of viscera

Starting 4/23 TEST #09 #17 moved to chest cavity block, above viscera

Figure 9 - ADAM Grid Thermocouple Setup

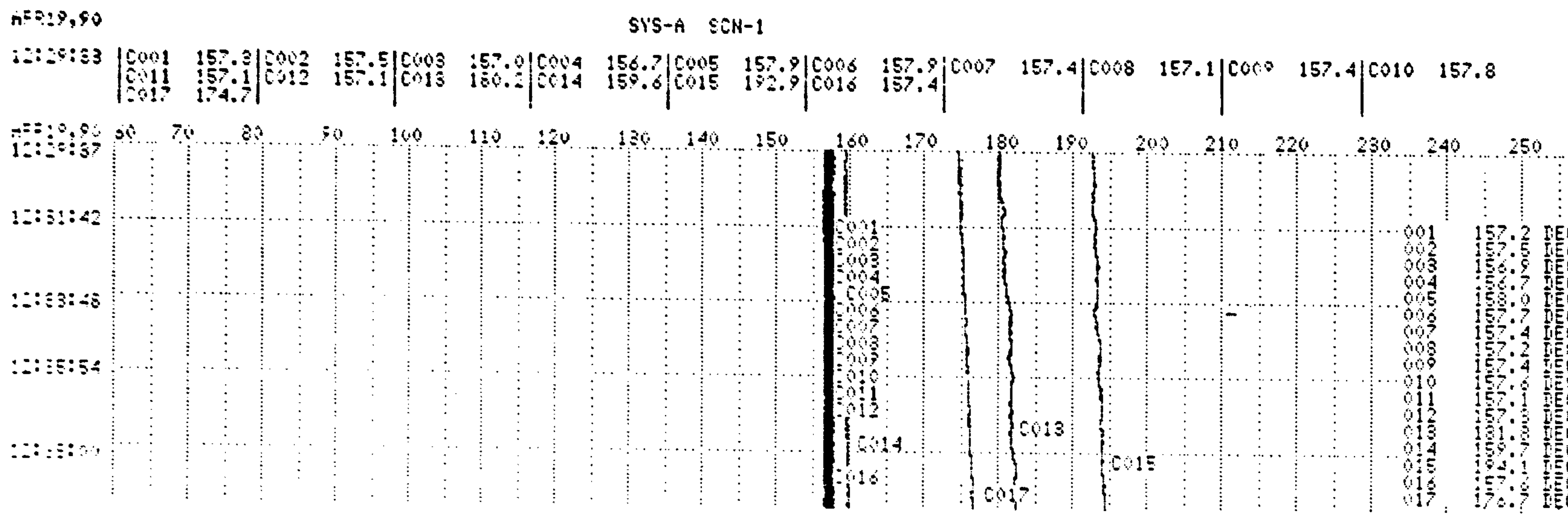


Figure 10 - Full Power Test, Temperature Profile Met

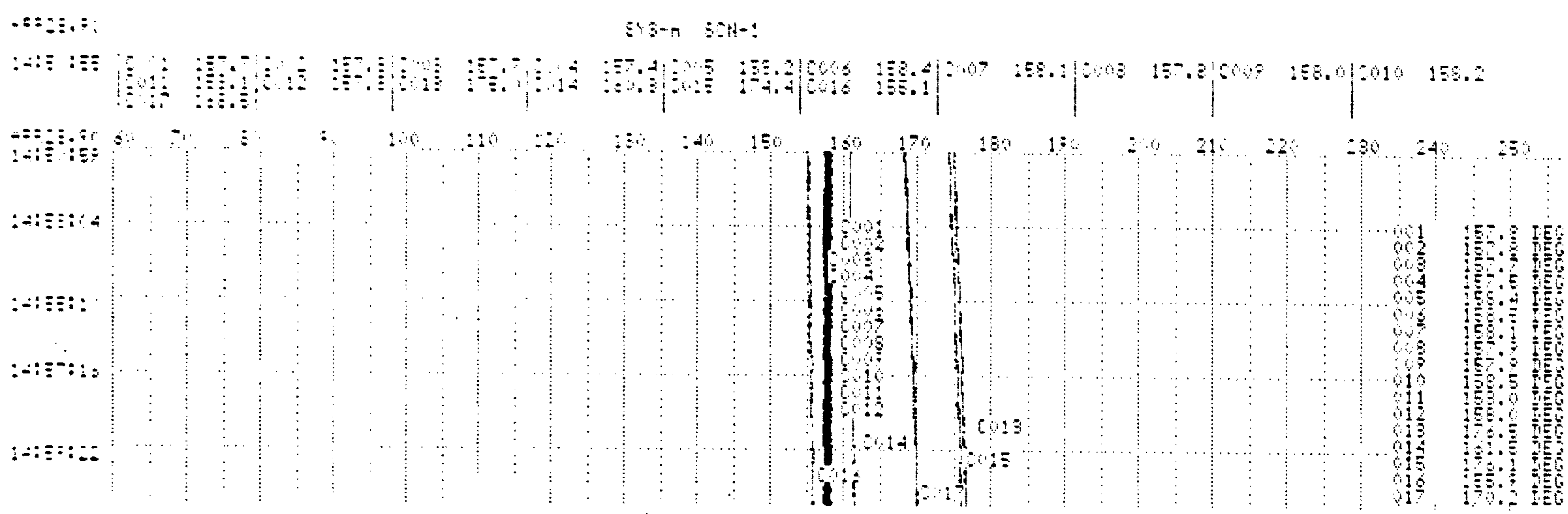


Figure 11 - Stand-by Test, Temperature Profile Met

shows, the viscera heats very quickly once ADAM is put on full power.

Effects of Outer Clothing Material on Viscera Temperature

The temperature profile, the ADAM power status, and the external clothing material have significant effects on the viscera temperature. Figure 13 shows the fourth profile just as the chamber temperature is reaching the first peak. This is taken from test #13, which is a stand-by test without external clothing. Notice that even with the digital circuits on in the viscera, the temperature inside the viscera is only as hot as the outside chamber due to the 90°/hr gradient of the profile. Compare this to Figure 14, test #14, which is taken from the same profile and the same point in the test. This is also a stand-by test, but ADAM is wearing the lycra suit. Notice that the viscera thermocouples #13 and #15 are 10-15°F cooler than the chamber. Here the lycra suit acts as an insulator, keeping ADAM cooler than the ambient air. Figures 15 and 16 demonstrate the same property of the outer clothing materials, except with these tests, #15 and #16, the ADAM is fully powered and in test #16 ADAM is wearing both the lycra and the flight suit. Figure 15 also shows that when ADAM is fully powered it heats quicker than the chamber at a 90°/hr gradient.

Comparing Figures 13 and 15 show that with the same profile, Figure 4, and no outer clothing material, but different power settings, that a gradient inside the viscera again exists. Thermocouple #13, at the top right side of the viscera, is almost identical between the two tests, 5°F above the ambient air. But thermocouple #15, top left side of the viscera, is 10°F hotter in test #15, Figure 15, than test #16, Figure 16. So a temperature gradient inside the viscera box is created when ADAM is fully powered regardless of the temperature gradient of the ambient air, compare Figures 10 and 15. Likewise, there is very consistent temperature distribution across the viscera in stand-by tests, which is also independent of the temperature gradient of the air, compare Figures 11 and 13.

The external clothing material revealed three distinct effects on the internal viscera temperature. For tests such as the high gradient tests or the fluctuating temperature tests, Figures 3 and 4, the outer clothing materials acted as insulation to keep the hotter ambient air away from ADAM. This was just discussed and shown in Figures 13-16. The second effect can be seen when comparing Figures 15 and 16. These figures correspond to tests #15 and #16 respectively, see Table 4. The only difference between these tests is in test #16 ADAM is wearing both suits. Thermocouple #13 is almost identically the same temperature in both figures, but in Figure 16 thermocouple #15 is not 10°F hotter as seen in Figure 15, but the same temperature as thermocouple #13. Therefore, the clothing materials in test #16

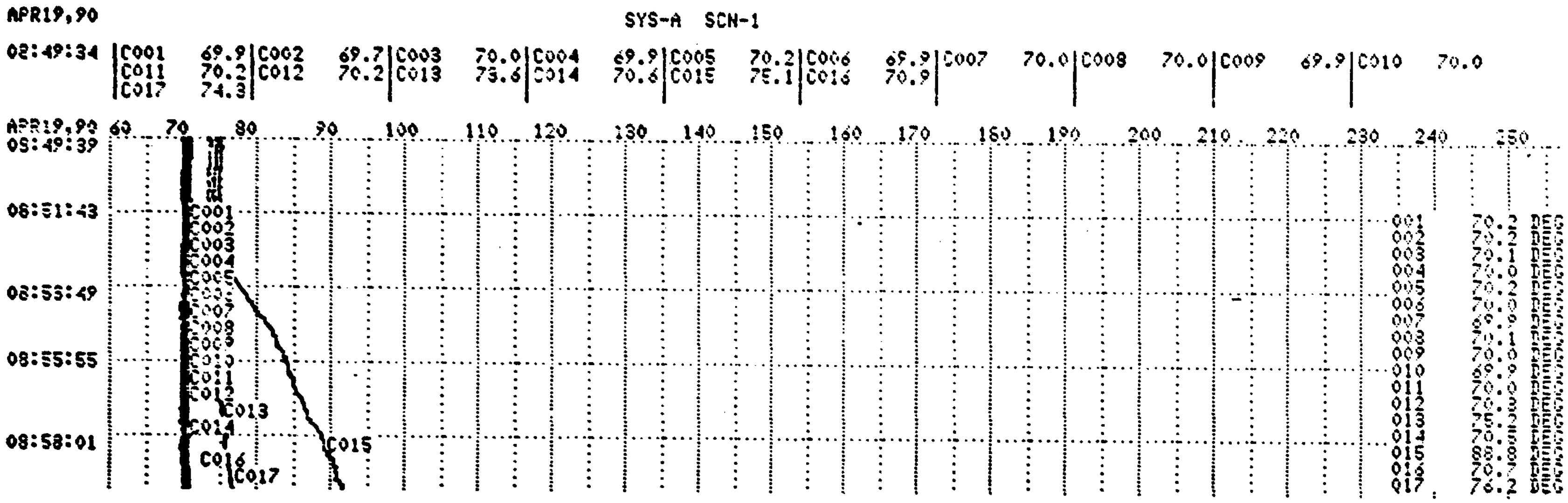


Figure 12 - Heating of Viscera Once Fully Powered

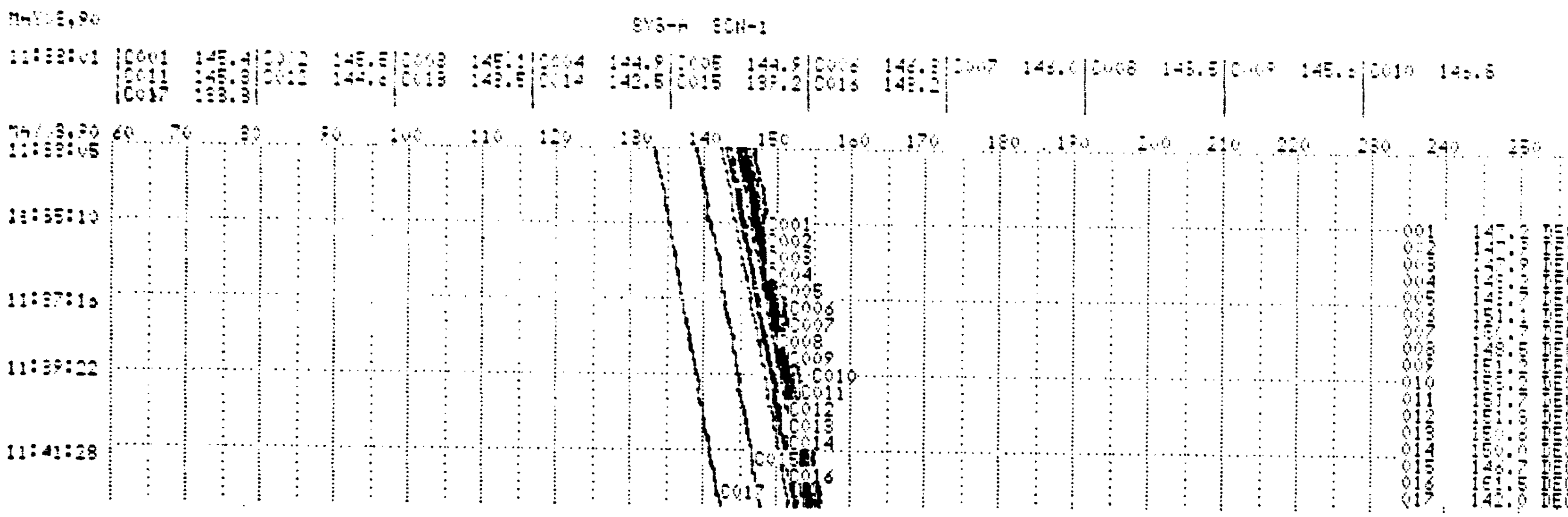


Figure 13 - Stand-by Test, Profile 4, First Peak, No Suit

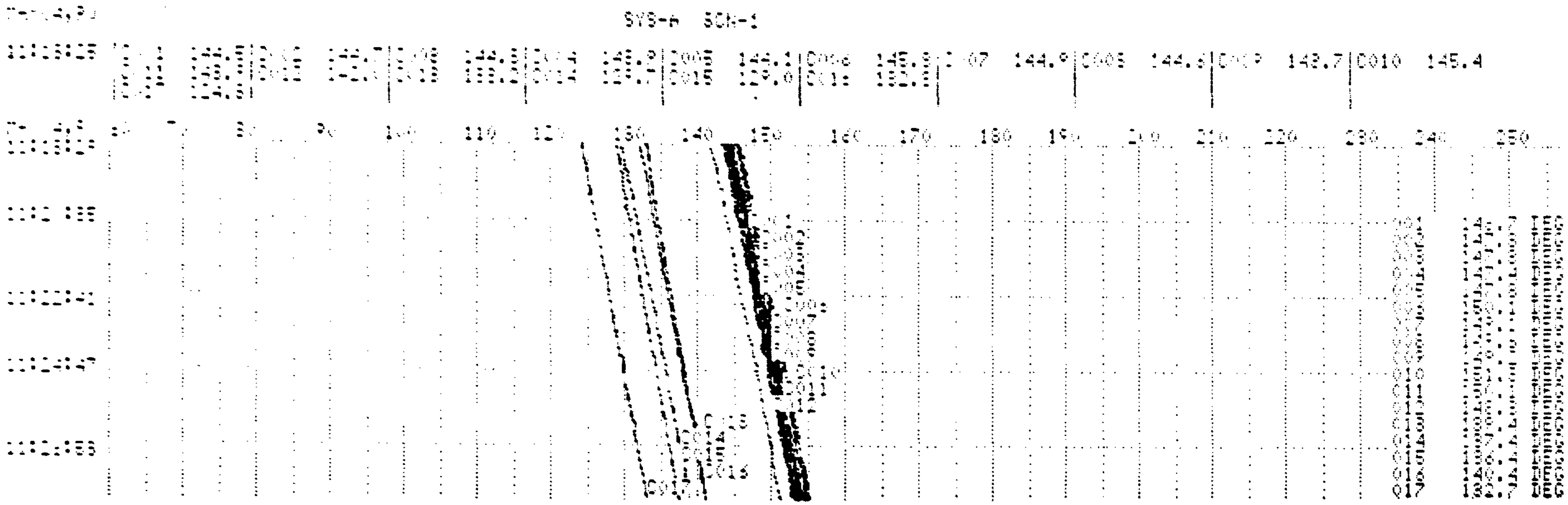


Figure 14 - Stand-by Test, Profile 4, First Peak, Lycra Suit

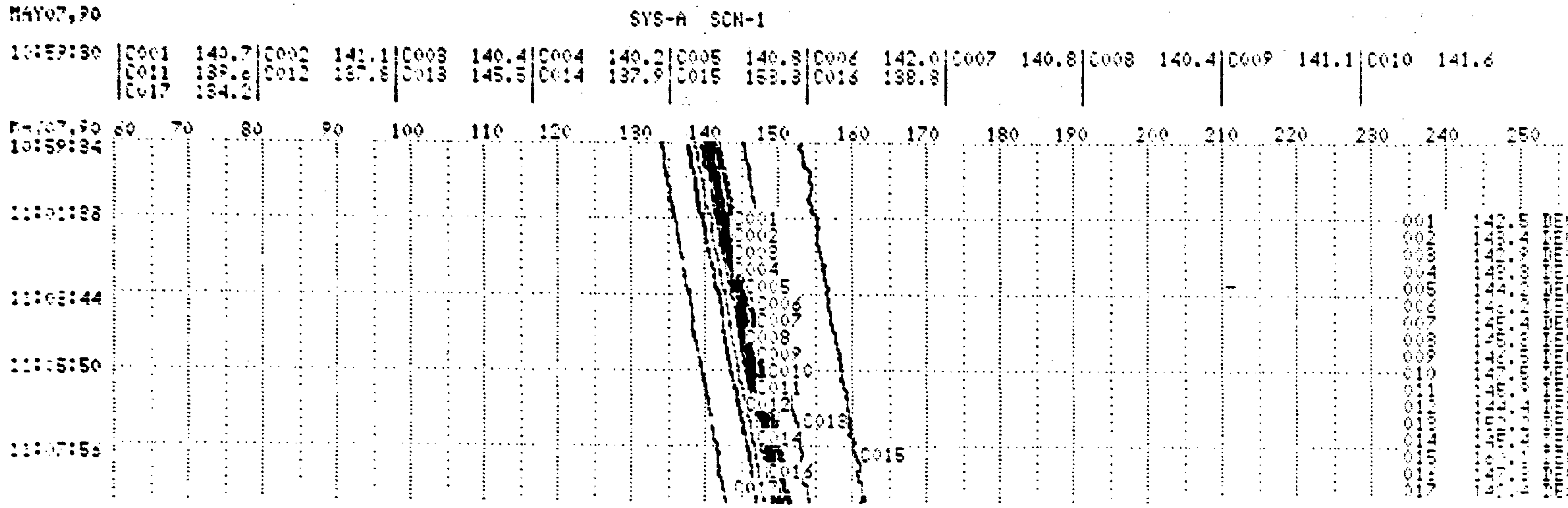


Figure 15 - Full Power Test, Profile 4, First Peak, No Suit

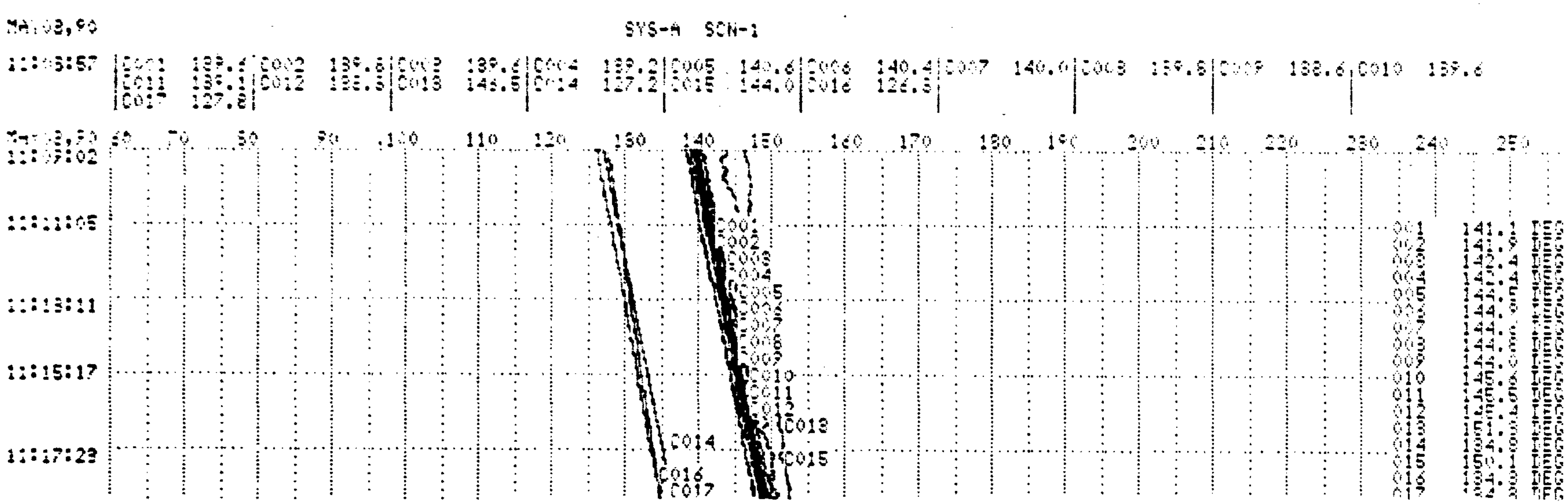


Figure 16 - Full Power Test, Profile 4, First Peak, Both Suits

have effectively canceled the temperature gradient across the viscera box in test #15. The third effect of the outer clothing material is it acts as an insulator to keep the hotter air around the manikin inside the clothing material. This can be seen for both stand-by and full power tests. Figures 17 and 18 show tests #5 and #7 respectively, which are both stand-by tests. Notice that the viscera temperature is 10°F higher when the lycra suit was worn. The same result occurred when the flight suit was worn. Similarly, the outer clothing materials kept the hotter viscera air trapped inside the manikin for the full power tests as well.

Viscera Heat Dissipation in Cyclic Tests

The fluctuating temperature tests, Figure 4, also provided some additional information about the viscera temperature in a rapidly changing ambient temperature environment. The four plots of Figure 19 show the ambient chamber and viscera temperatures just as the profile has reached the first peak and follows it to the valley between the first and second peak of test #15, full power. Notice that about 10 minutes after the profile has begun cooling the chamber, the viscera temperature is not steady, but after 10 more minutes the viscera has begun to cool. The four plots of Figure 20 show the slope of the profile of the same test after reaching the second peak. The time for the viscera temperature to stabilize and then to cool are the same, but the viscera thermocouples, #13 and #15, are measuring 5-8°F hotter after the second peak than after the first. This shows that even though the profile drops the temperature to 70°F before climbing again, the viscera is not able to dissipate enough heat as the chamber cools to return the temperature to what it was the previous cycle. Figures 21 and 22 show the same conditions for a stand-by test, test #13. The time to stabilize and cool are slightly accelerated for the stand-by test. Also, when comparing the last plot of Figures 21 and 22, it is shown that the viscera was able to dissipate enough heat so that both cycles had matching viscera temperatures.

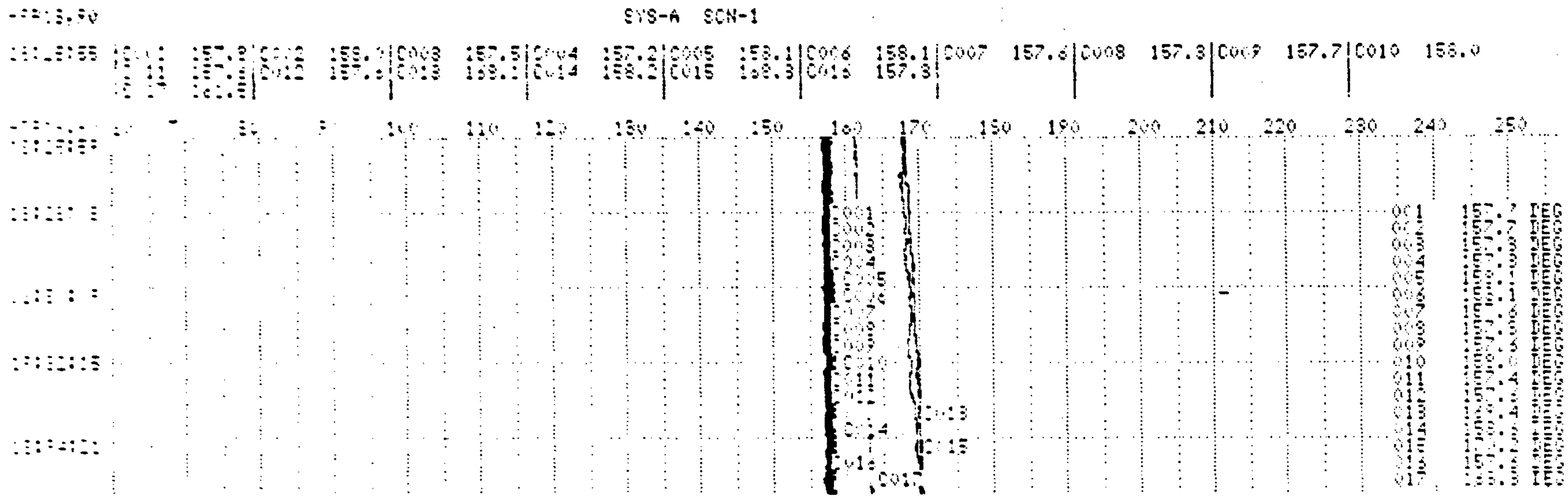


Figure 17 - Stand-by Test, Profile 2, Soaking, No Suit

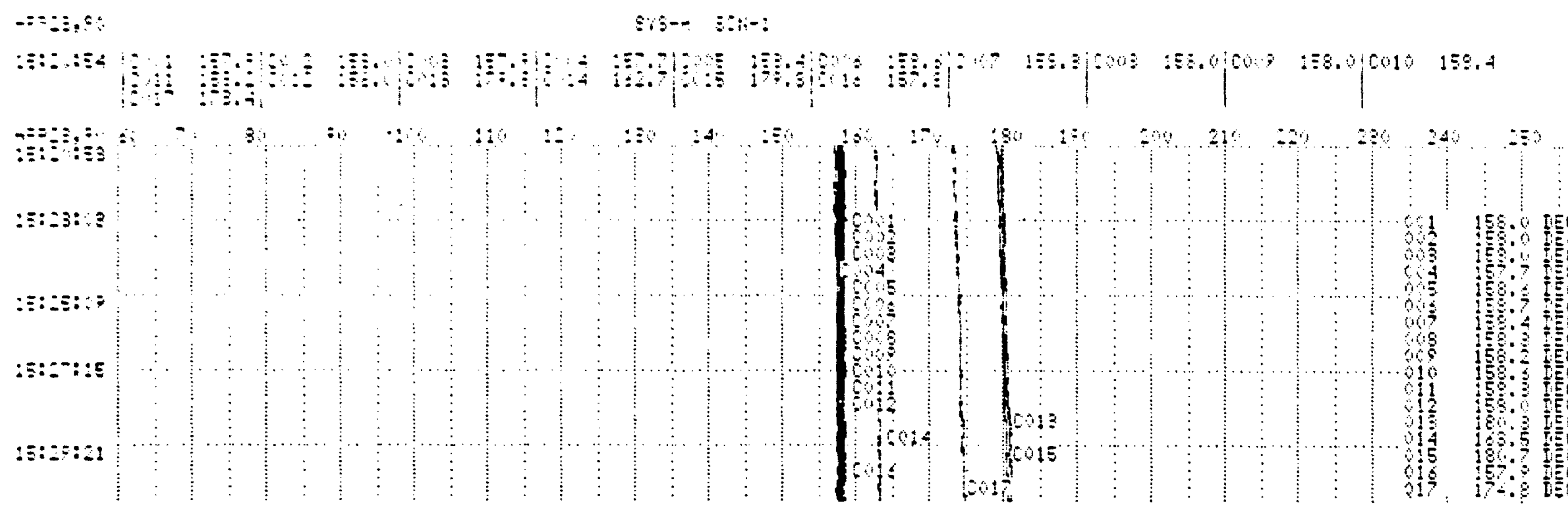


Figure 18 - Stand-by Test, Profile 2, Soaking, Lycra Suit

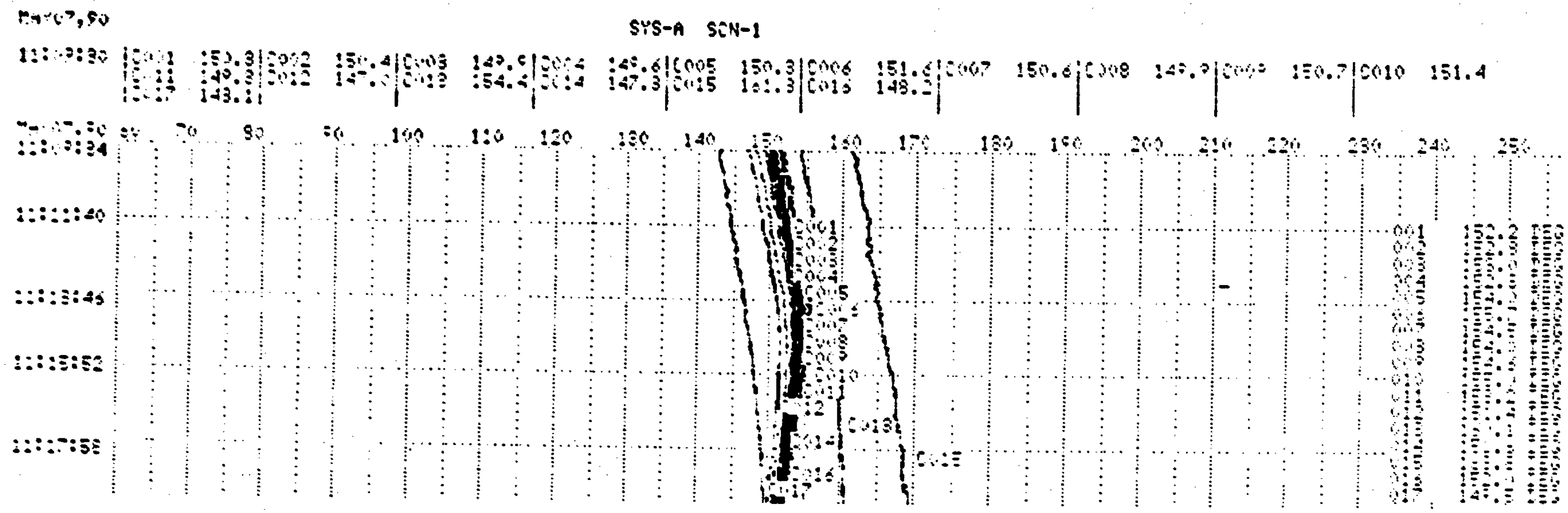
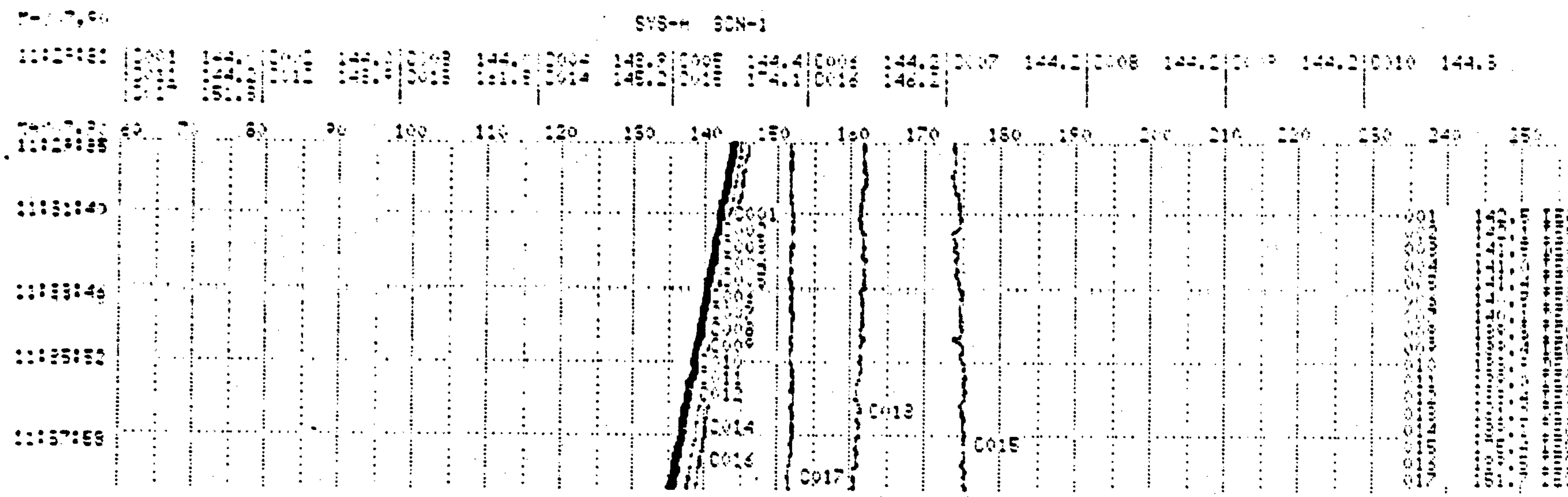


Figure 19 - Full Power Test, Profile 4, After First Peak, No Suit
(1 of 4)



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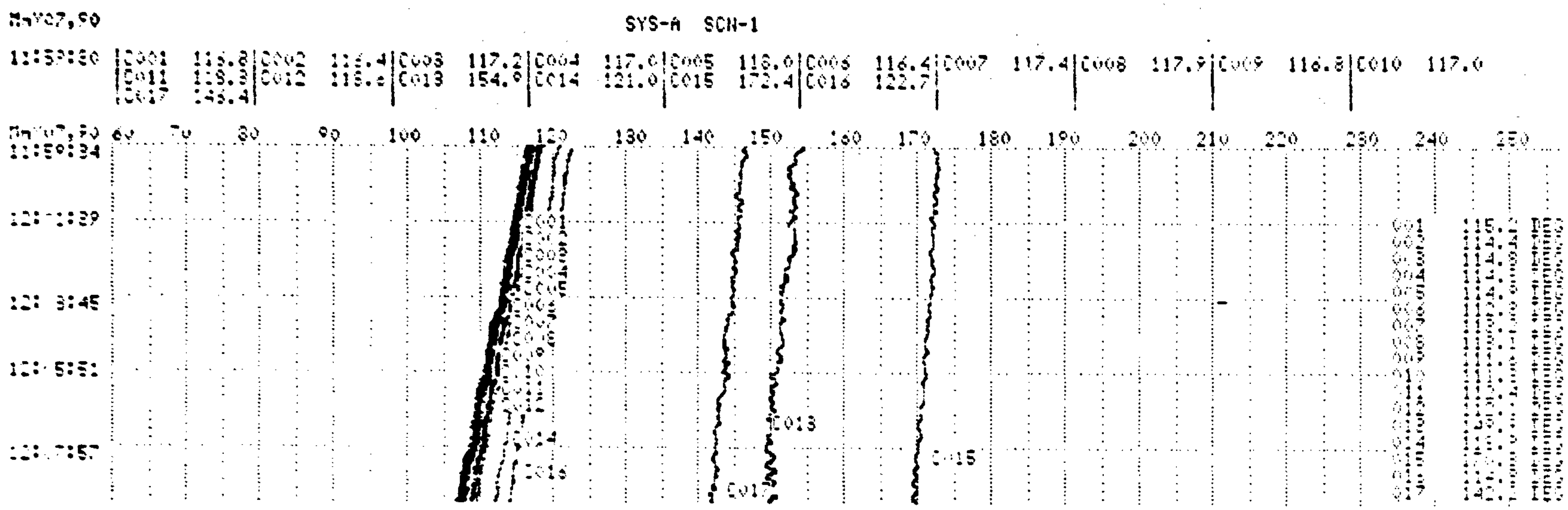
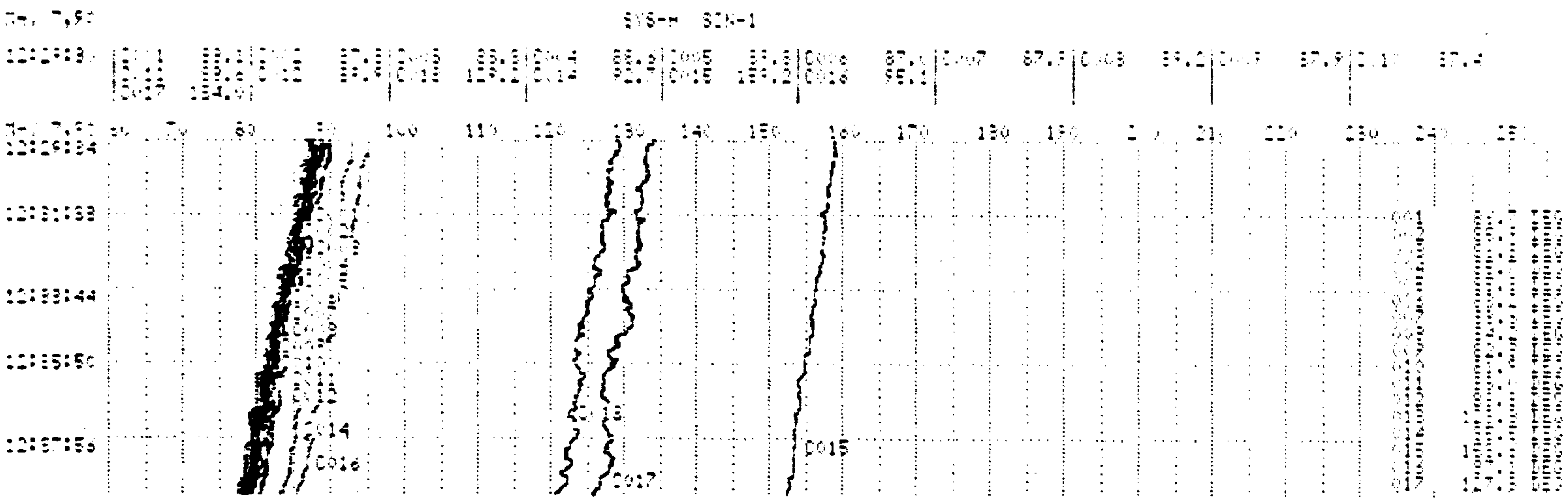


Figure 19 - Full Power Test, Profile 4, After First Peak, No Suit
(3 of 4)



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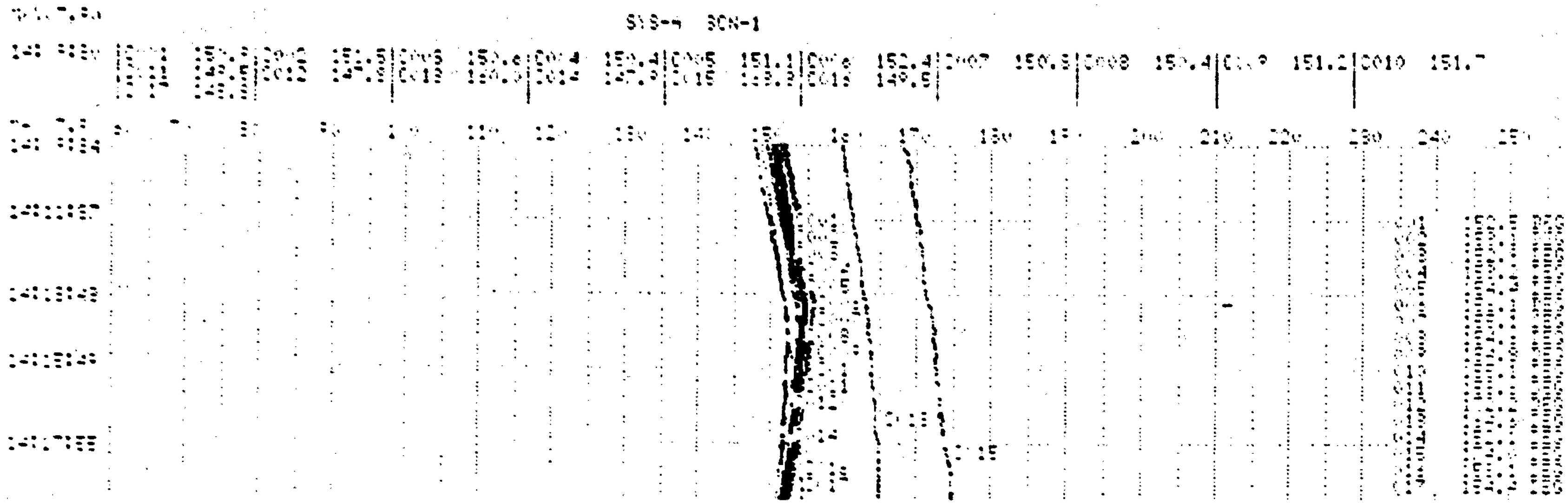
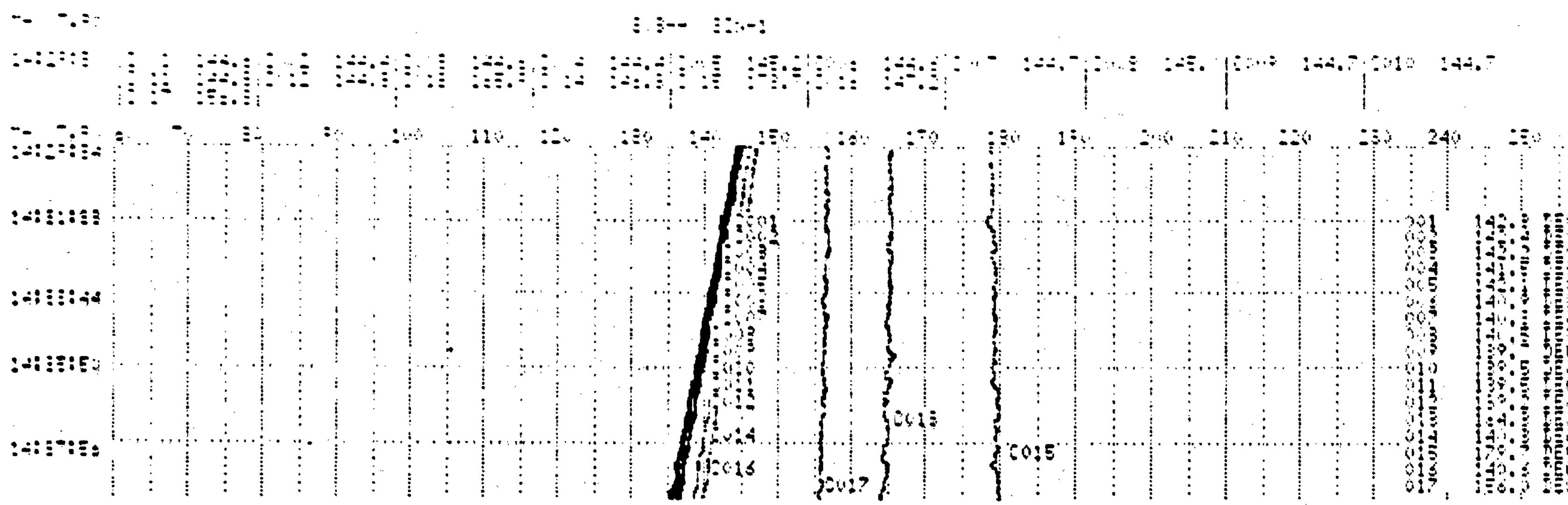


Figure 20 - Full Power Test, Profile 4, After Second Peak, No Suit
(1 of 4)



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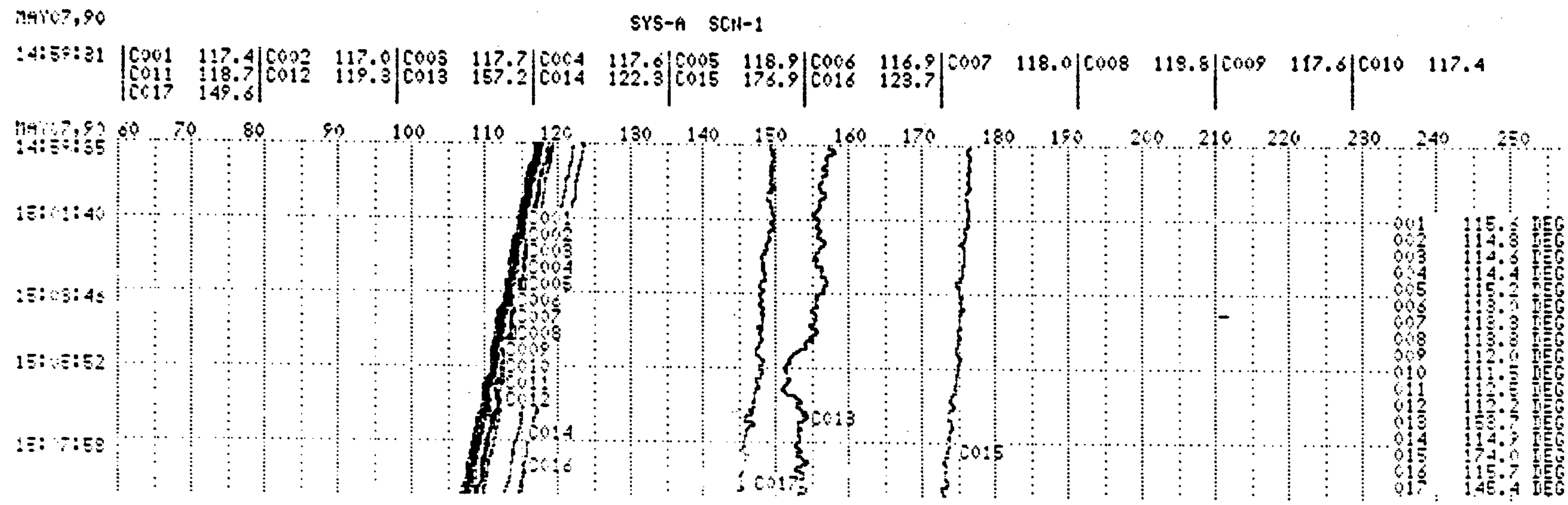
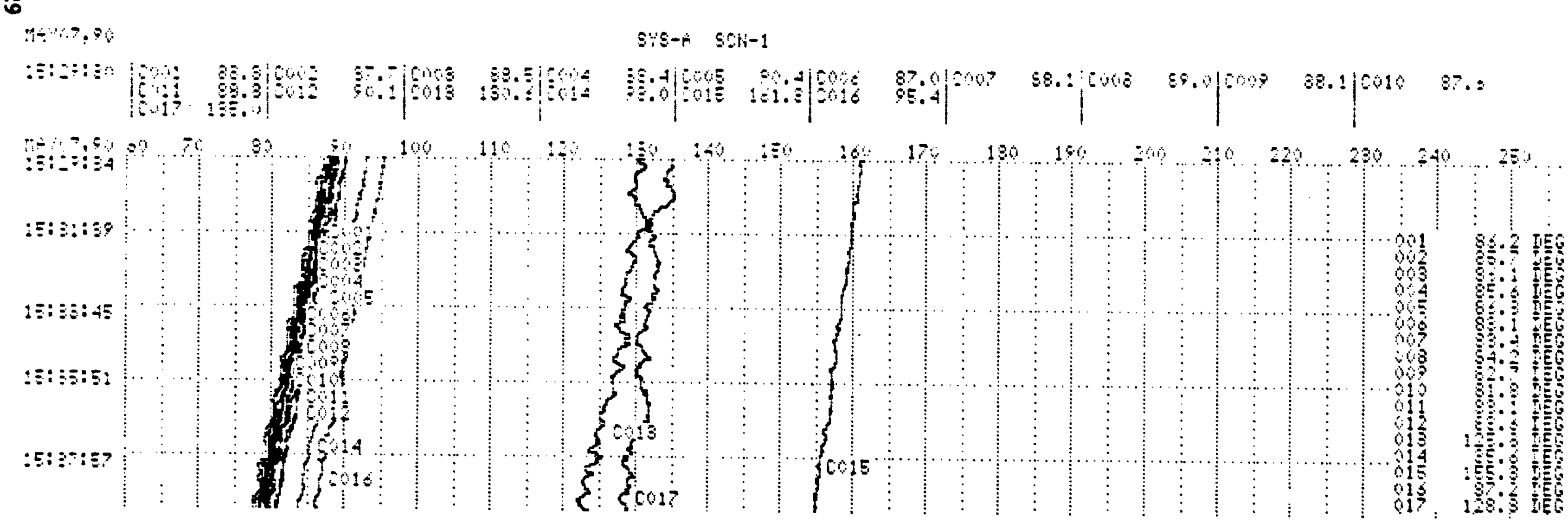


Figure 20 - Full Power Test, Profile 4, After Second Peak, No Suit
(3 of 4)



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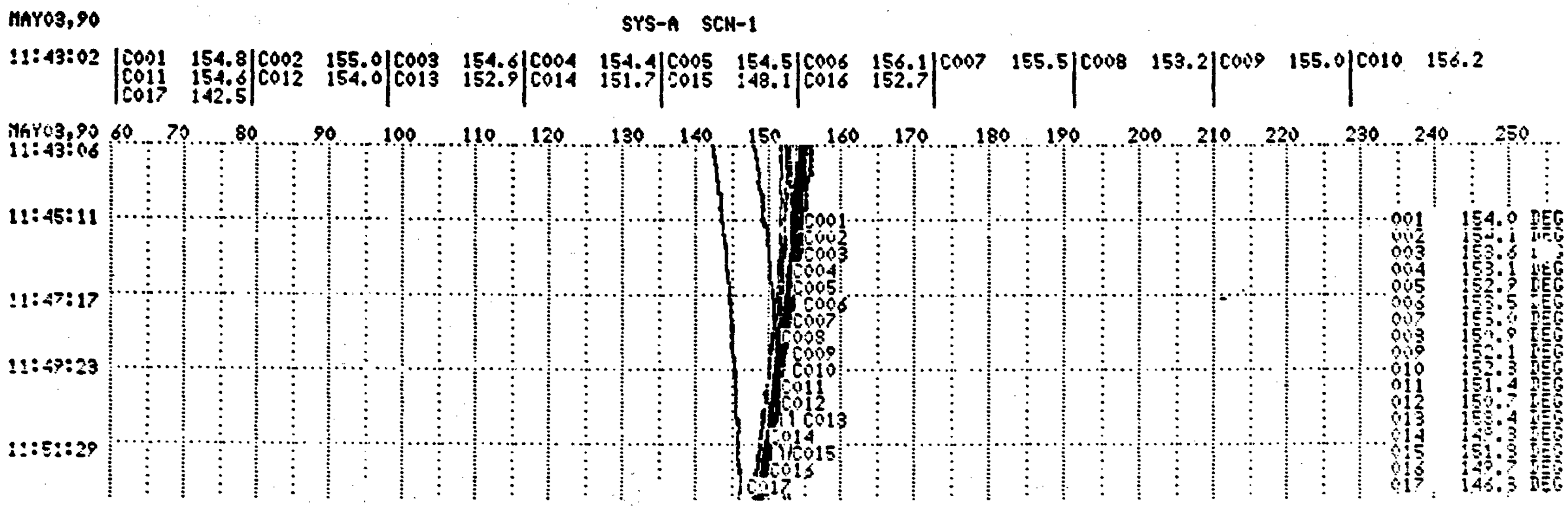
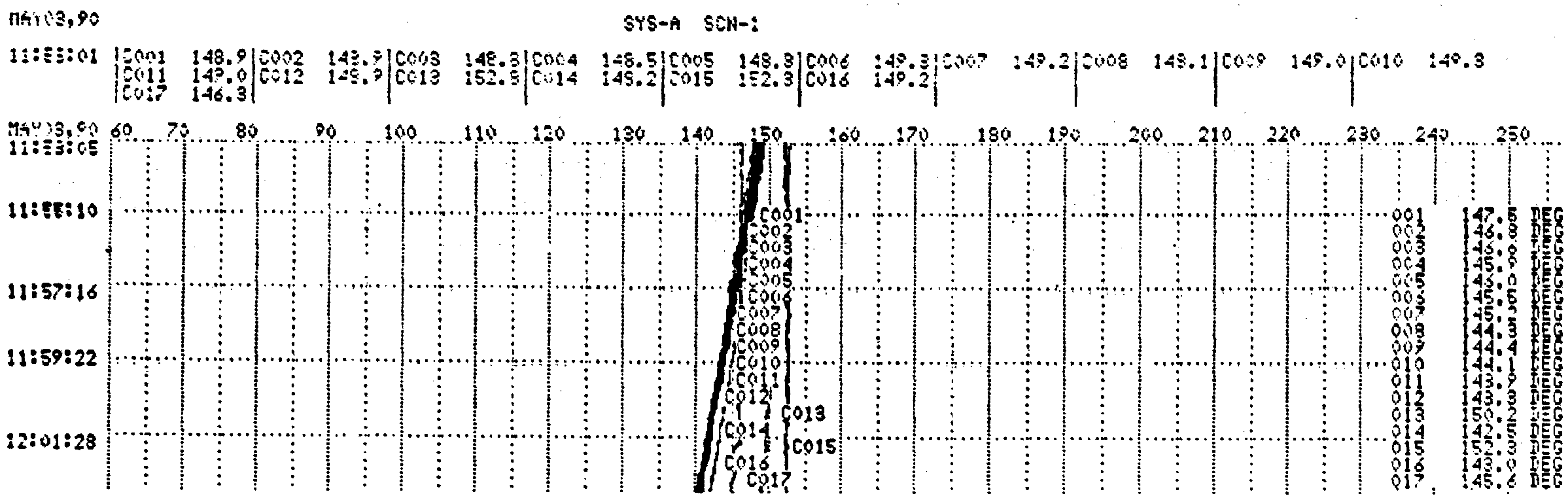


Figure 21 - Stand-by Test, Profile 4, After First Peak, No Suit
(1 of 4)



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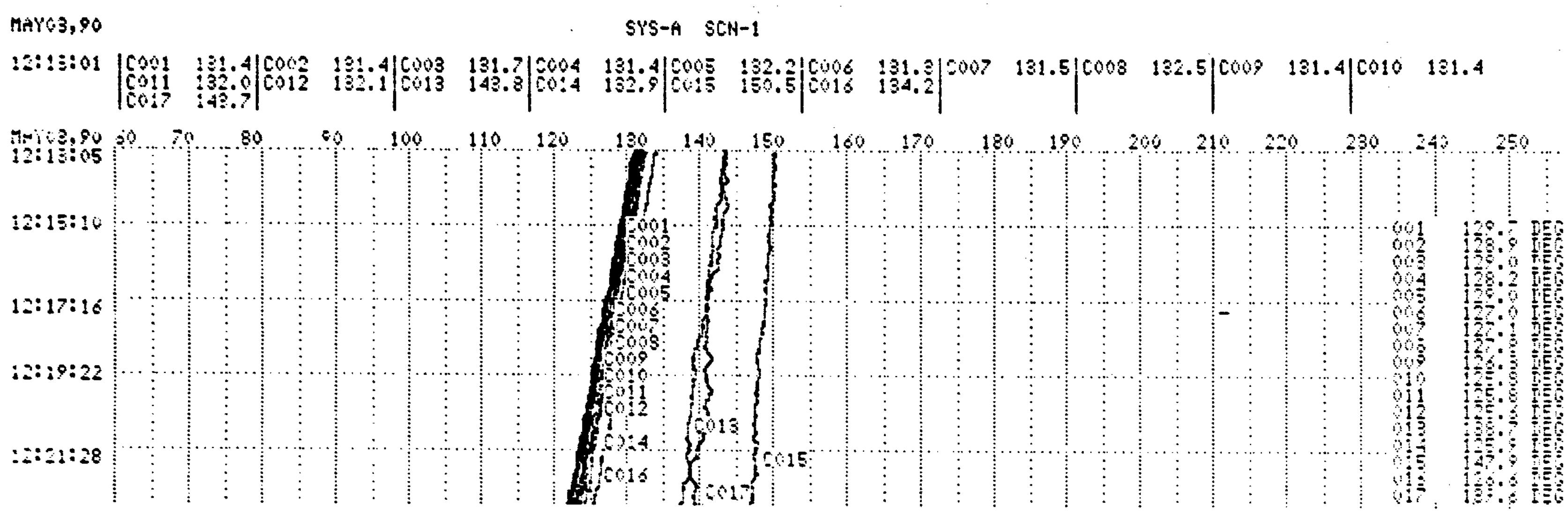
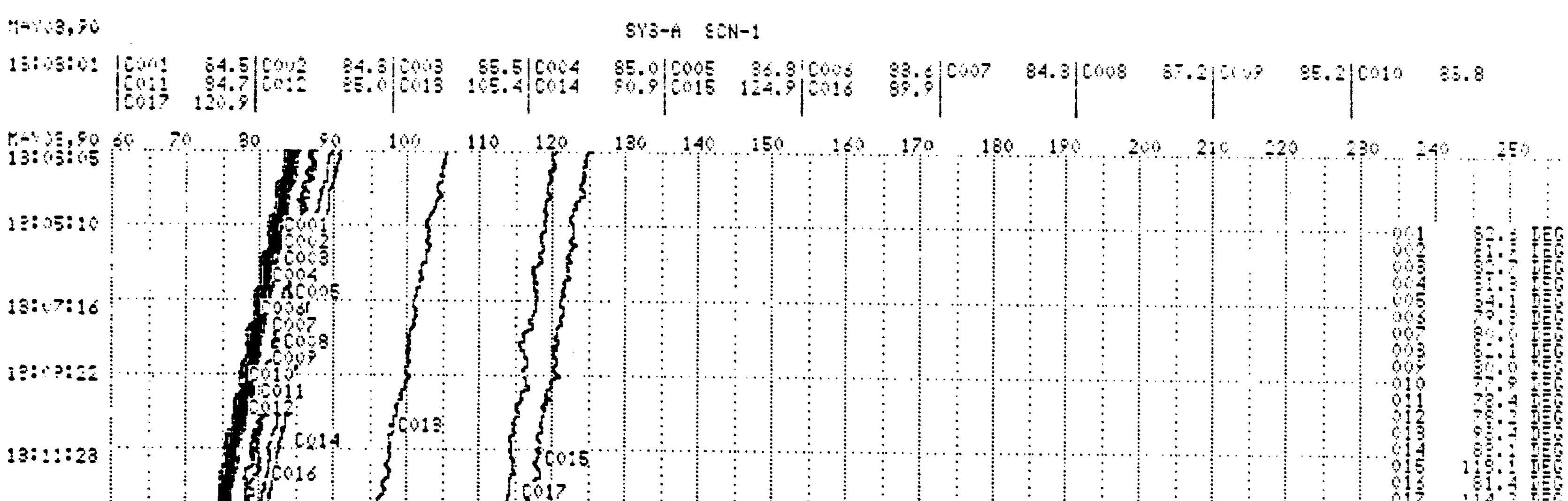


Figure 21 - Stand-by Test, Profile 4, After First Peak, No Suit
(3 of 4)



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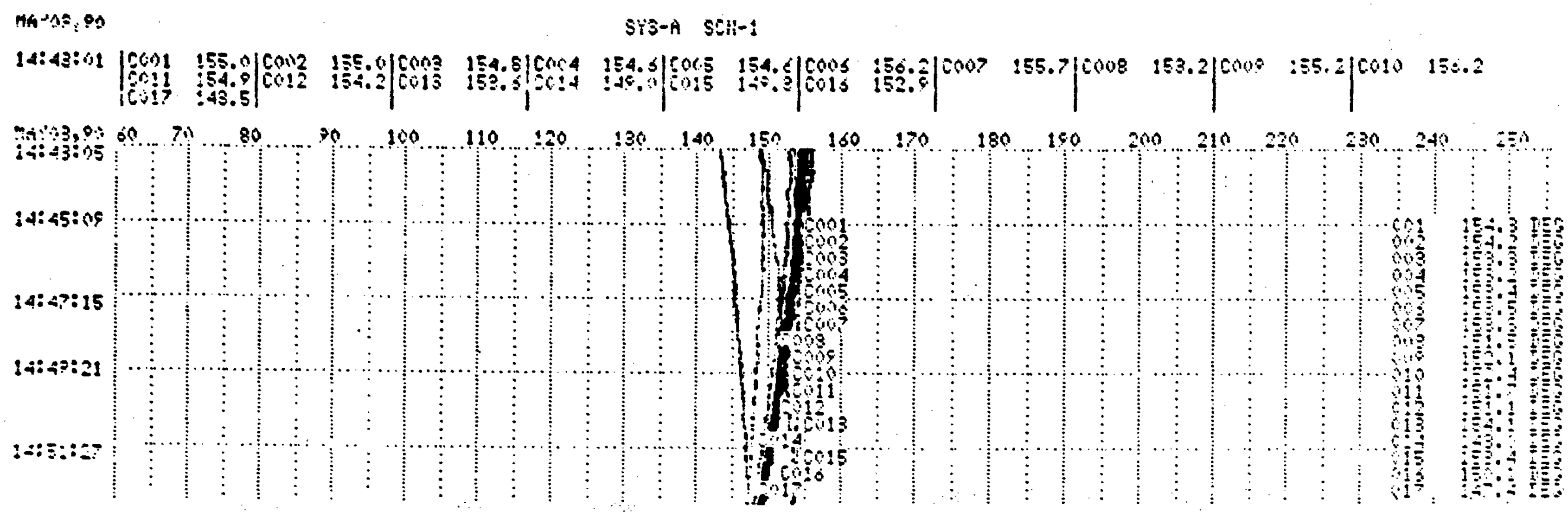
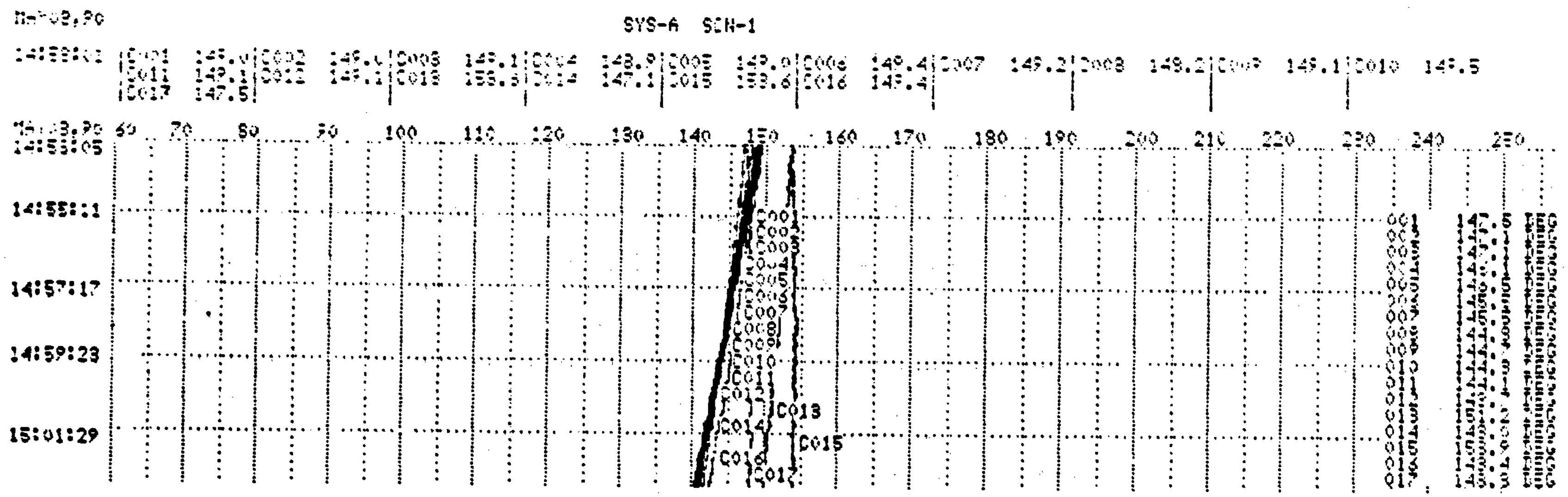


Figure 22 - Stand-by Test, Profile 4, After Second Peak, No Suit
(1 of 4)



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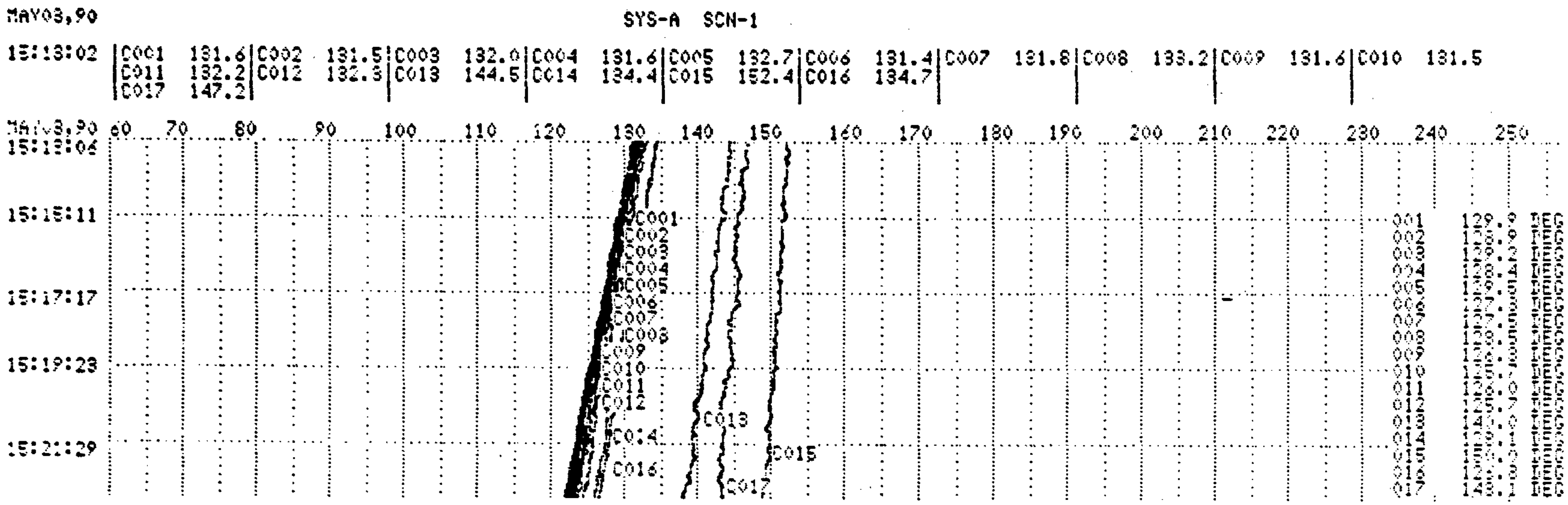
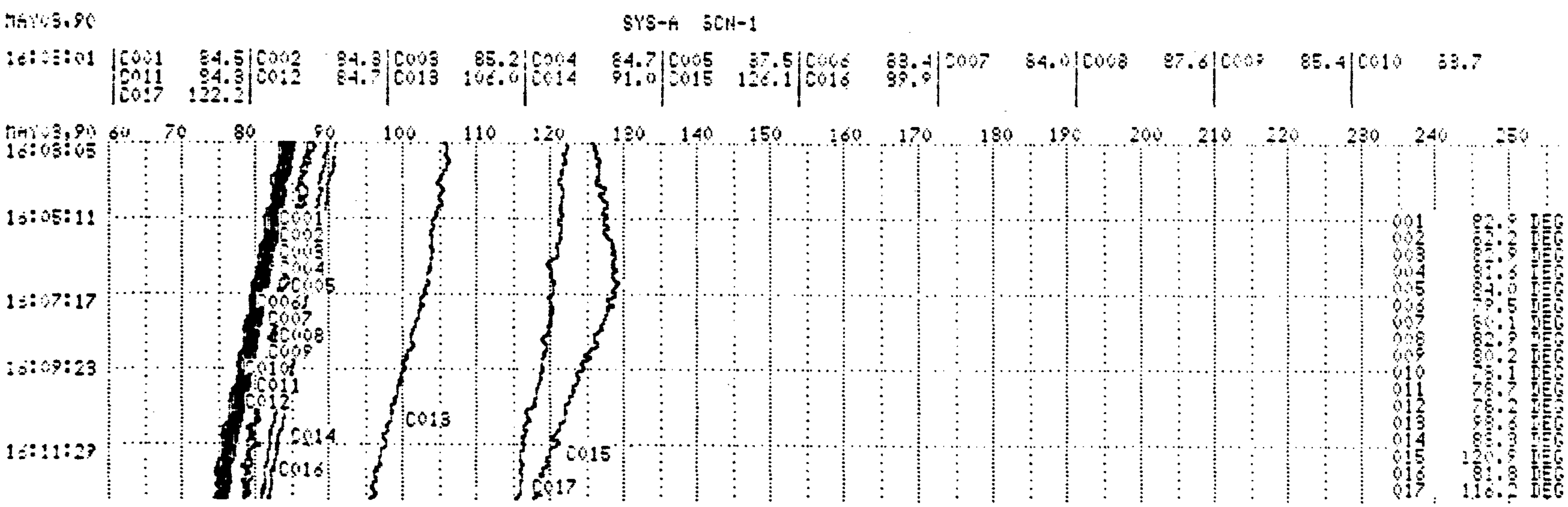


Figure 22 - Stand-by Test, Profile 4, After Second Peak, No Suit
(3 of 4)



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SAFE OPERATIONAL TEMPERATURE THRESHOLD

Background for the Safe Operational Temperature Threshold

The determination of the safe operational temperature threshold is based upon the performance of the manikin throughout all 16 tests. The ability to operate properly in all of the various thermal profiles, Figures 1-4, were a prime interest. It must be stated that the profiles were created to represent possible thermal scenarios ADAM may face at Holloman AFB, NM, but the magnitudes of the profiles were amplified to the point that ADAM was expected to shut down in 50% of the tests. Figures 23-26 illustrate ADAM's internal temperature probe measurements for every data dump in each test each profile. ADAM's internal temperature probe can only collect data when the manikin is fully powered, so the curves that are connecting the points are not the actual temperatures between the data dumps, but a fifth order curve fit that approximates the temperatures. The only real deviation occurs at the end of tests when ADAM shuts down and data could not be collected. Typically ADAM would be put on stand-by and allowed to cool to a temperature that might be low enough to allow the system to operate. If the system was still shut down, either ADAM was allowed to continue cooling while on stand-by or completely turned off, allowing the viscera to cool very quickly. Once data were collected, the temperature measured by the internal temperature probe was calculated and displayed on the graphs. In five of the tests the computers controlling the Thermotron unit were reprogrammed to cool the chamber. This occurred for the last test of the first profile, Figure 1, and all four tests of the second profile, Figure 2. These profiles were desigred as a ramp up to a high temperature and then a soak at that temperature. This allowed the viscera temperature to continue rising throughout the entire test. Once communication was lost with the manikin or it failed to download data, it would not reset itself until the viscera was cooled. After the manikin was put on stand-by or turned off to cool and data later collected, the mission profile was stopped.

Safe Viscera Operational Temperature Threshold

As the test notes describe in detail, see Appendix, a specific manikin shut down temperature was sought. This temperature was found to be 185°F on thermocouples #13 and #15. The internal manikin temperature probe measured temperatures up to 242°F, but in other tests the last measured temperature was 200°F before manikin shut down. The accuracy of the internal temperature probe may have a slight effect on the measured values since the resolution is +/-2.8125°F. This is determined by dividing the range of the output voltage, 4 volts, by the resolution of the digital system, 8 bits, which is 2^8 or 256 and multiplying by the

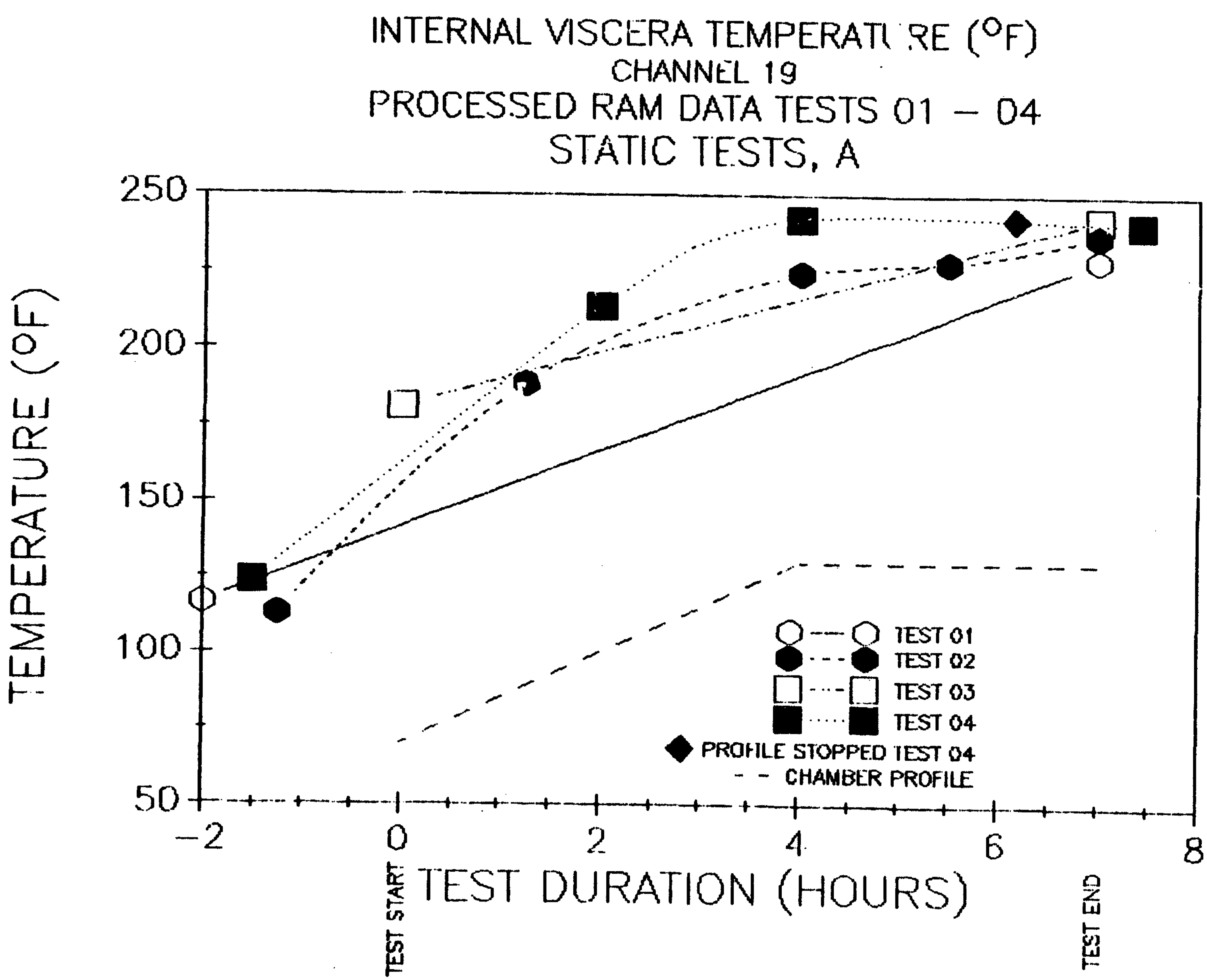

Figure 23 - Profile 1, Internal Temperature Probe Measurements

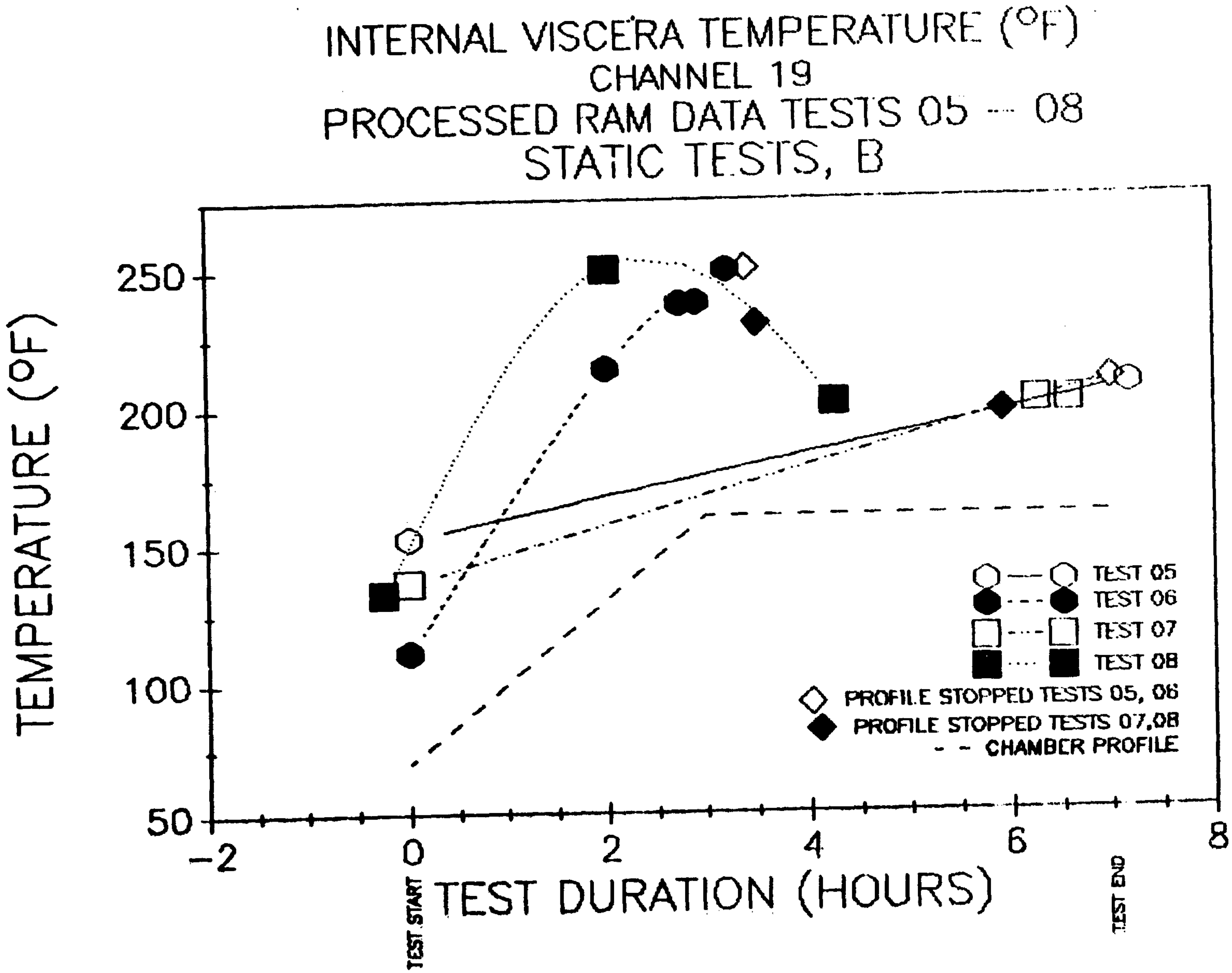

Figure 24 - Profile 2, Internal Temperature Probe Measurements

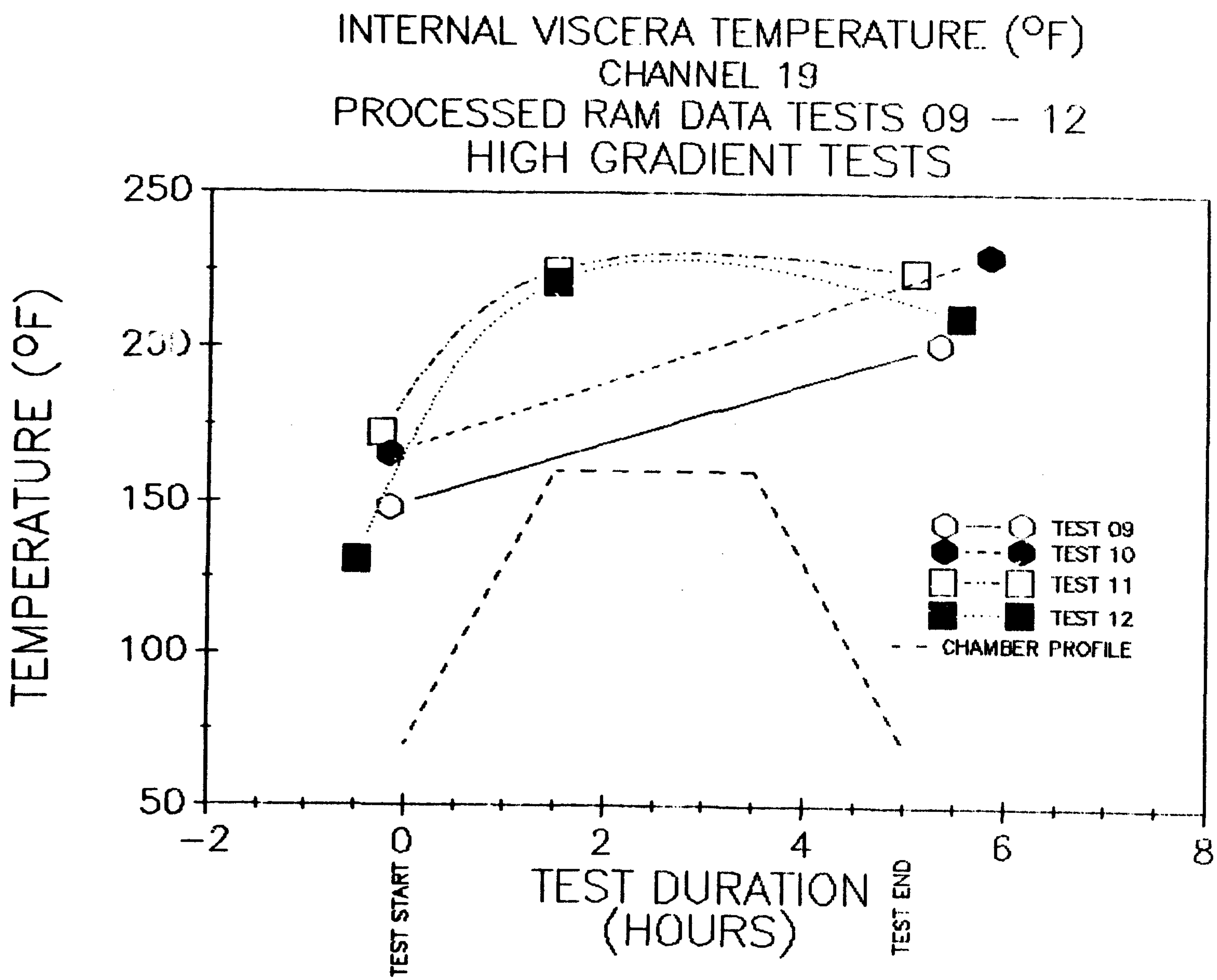

Figure 25 - Profile 3, Internal Temperature Probe Measurements

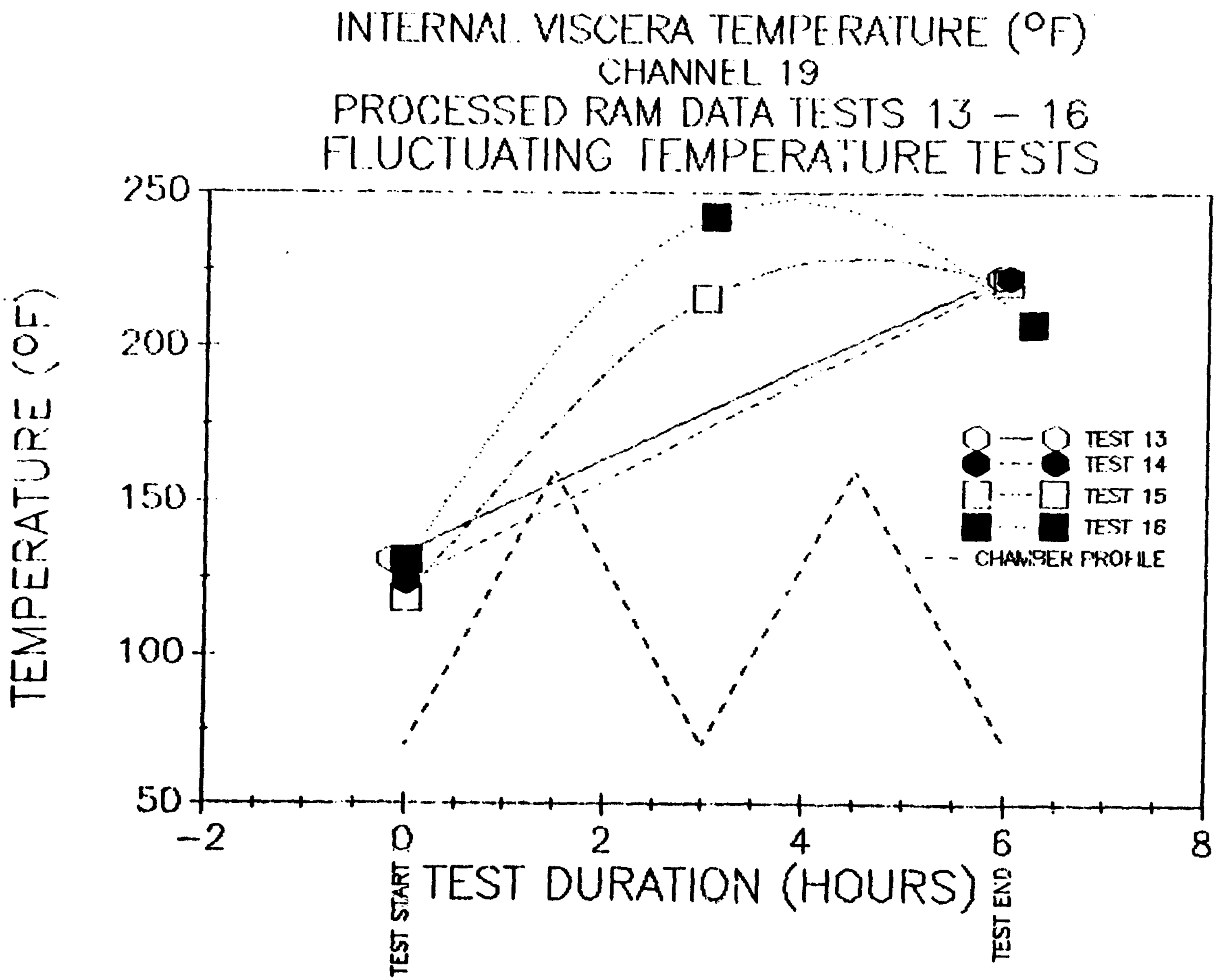

Figure 26 - Profile 4, Internal Temperature Probe Measurements

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Fahrenheit conversion factor of 180. This yields a resolution of 2.8125°F. The only unknown is the temperature of the internal probe during a stand-by test. It has been discussed previously that varying the thermal profile, or outer clothing materials can significantly affect the temperature and the temperature gradient inside the viscera box. Due to the potential hazard of electrical contact between a thermocouple and the circuit card assembly at the base of the viscera box, no thermocouple data was collected from that area. Cross-referencing the internal temperature probe data to the thermocouple data, it was determined that data collection never failed below 180°F. This temperature limit will allow data collection and transfer for any of the tested thermal profiles under any of the test specifics shown in Tables 1-4.

Safe Ambient Operational Temperature Threshold

Shown in Figures 27-30 are all attempted and failed data collections. Every profile had at least one test when ADAM shut down, therefore to be completely correct the safe ambient operational temperature threshold should be below the lowest tested maximum temperature, 130°F. Since no additional tests could be performed due to time restrictions, the safe ambient operational temperature threshold was established at 130°F with one caveat. In a thermally worst case test at 130°F, with full power and both outer garments, ADAM should not soak longer than two hours at 130°F to avoid shut down. These safe operational temperature thresholds are conservative, and ADAM was able to download data at internal and ambient temperatures above these respective thresholds.

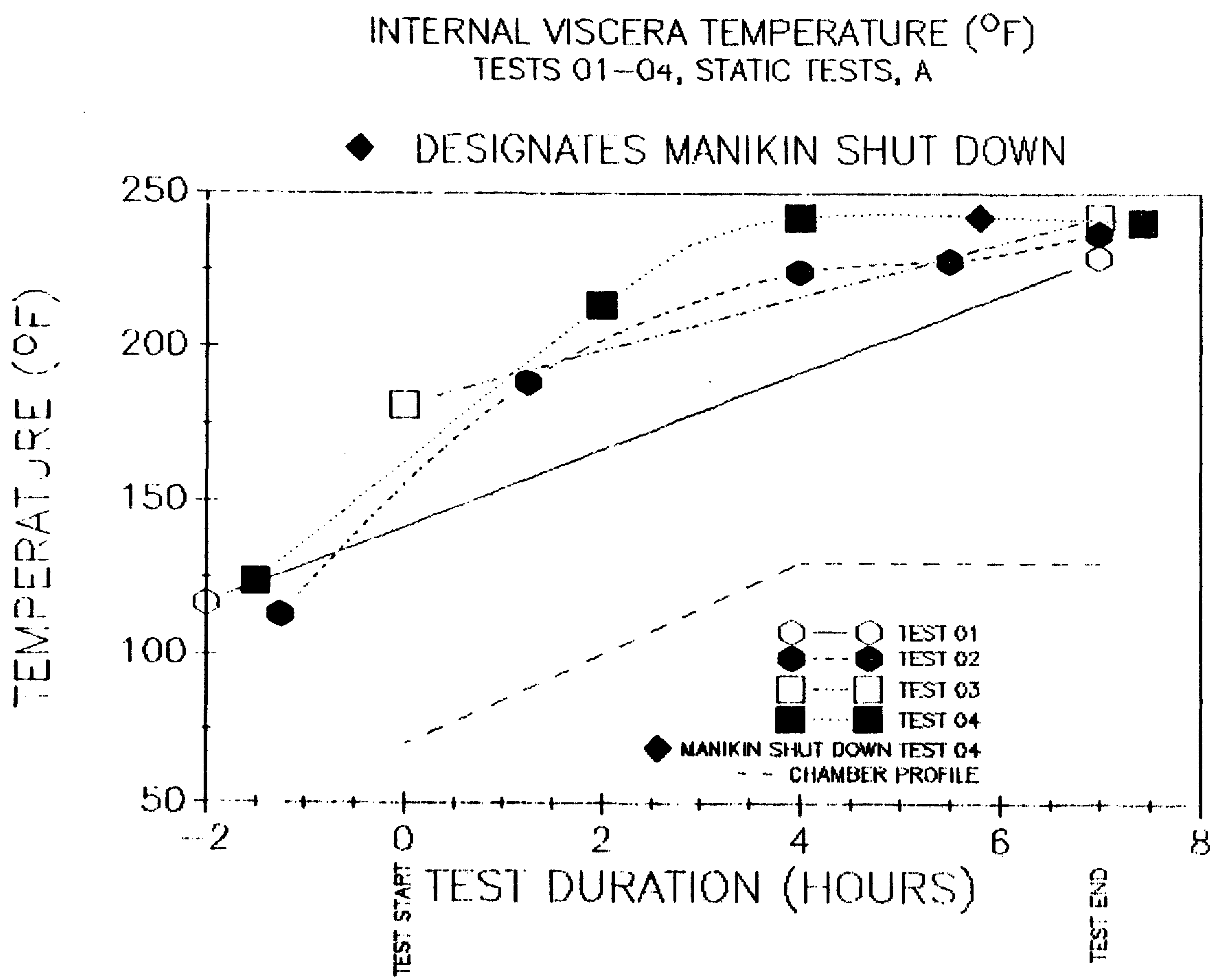

Figure 27 - Profile 1, Display of Manikin Shutdown

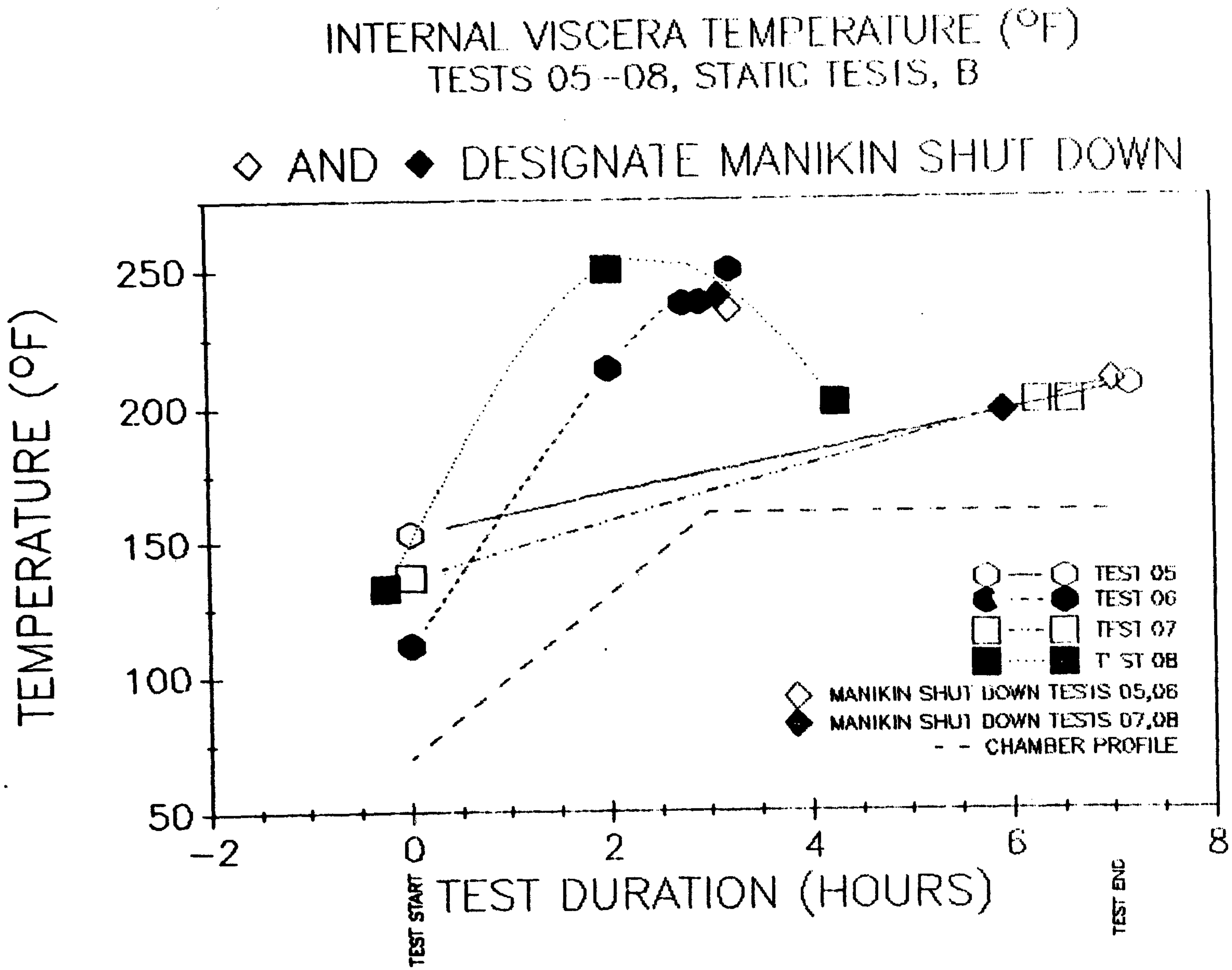

Figure 28 - Profile 2, Display of Manikin Shutdown

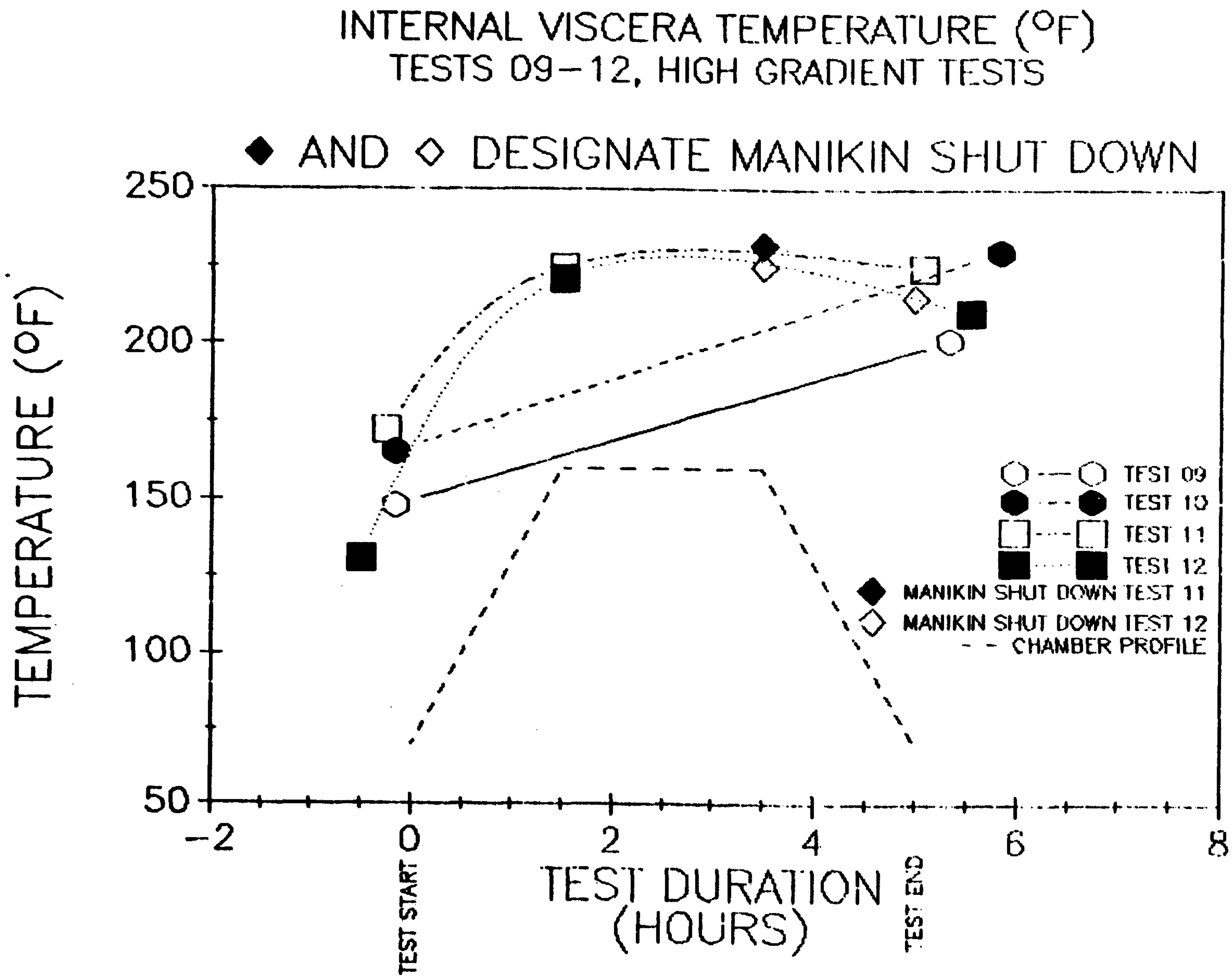

Figure 29 - Profile 3, Display of Manikin Shutdown

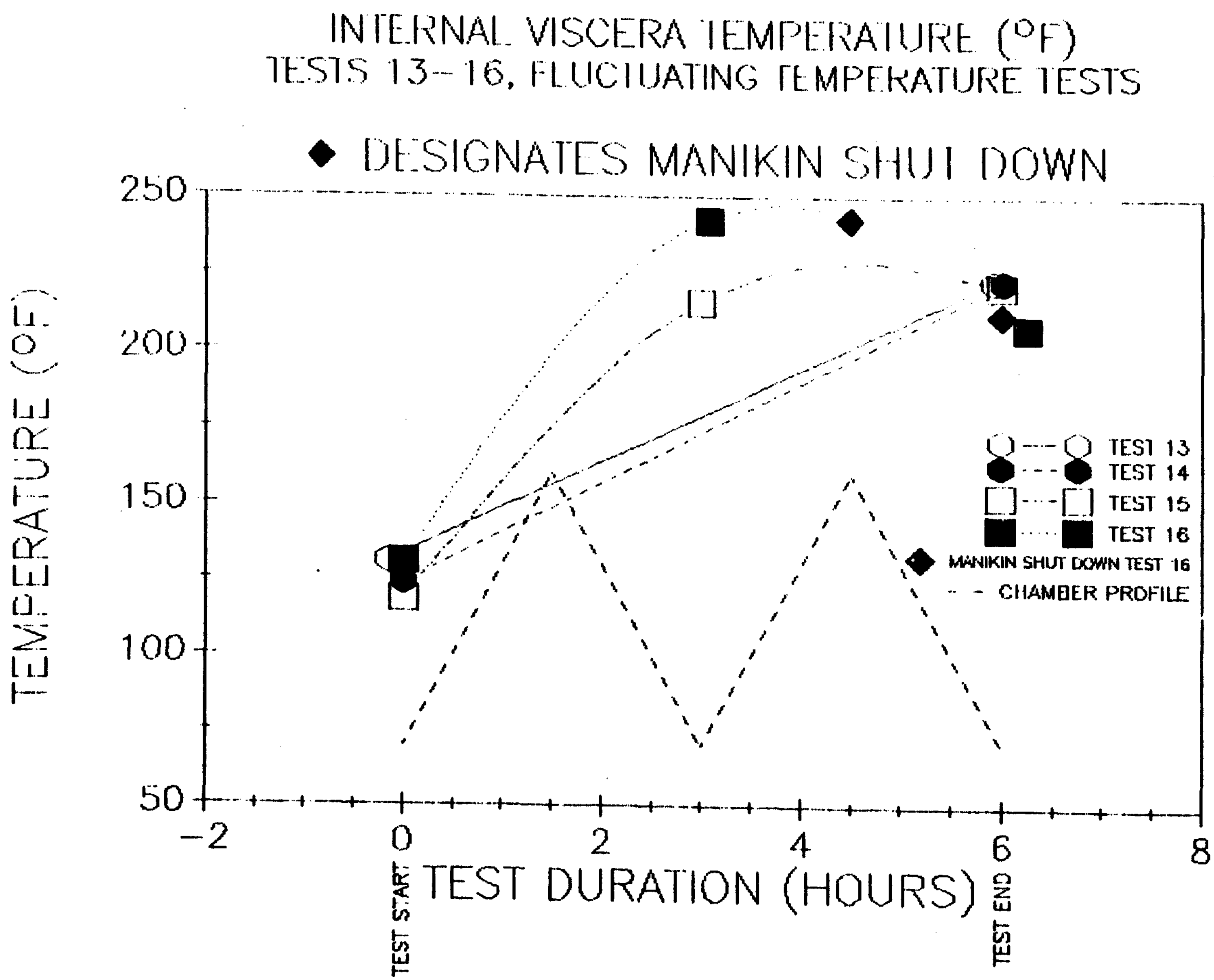

Figure 30 - Profile 4, Display of Manikin Shutdown

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ADAM DATA ACQUISITION SYSTEM SHUTDOWN

Background

The primary purpose for conducting these thermal tests was to determine a temperature threshold for safe operation and identify sources causing manikin shutdown above this temperature. In the 1987 thermal tests it was noted that the manikin may not collect data after being exposed to high ambient temperatures. It was also noted that after the manikin cooled, and the system was able to be rebooted, the manikin would work fine. There was no apparent permanent damage to the system. This led to the conclusion that certain components inside the viscera were merely shutting off once they became too hot. After they cooled, they would function normally again. What was not determined were the components that were shutting down. Although the purpose of these tests was to localize sources of manikin shut downs, this test program was not able to successfully isolate individual components that were causing the system to shut down. Additional bench testing of these individual circuits or boards could be performed to locate the components that are shutting down at high temperatures.

Many components in the viscera were not heated to their maximum suggested operating temperature, others reached the maximum, and a few operated above their maximum suggested operating temperature. Several circuits that exceeded their maximum temperature range are the hybrid circuits and the analog 8 pole butterworth filters, which have a maximum suggested operating temperature of 158°F.

System Shutdown

In order to explain how the circuits that shut down were located, it is important to discuss the exact procedure that occurred during the time just preceding a manikin shutdown. Once data had been collected at temperatures near 180°F, as measured by the viscera thermocouples, ADAM was closely monitored to determine its operational status. Using the handheld terminal,a single MUX of RCAL and NONRCAL hexadecimal calibration numbers were continuously monitored. This consisted of using the video display unit (VDU) to continuously "talk" to ADAM through the digital circuits to continuously monitor the calibration status of several sensors in the same MUX. The hexadecimal numbers displayed on the handheld terminal would be continuously updated by ADAM, as long as it was communicating with the VDU. Although the calibration numbers remained very nearly constant throughout a test, varying only one or two hex in most tests, very often the VDU display would show a RCAL or NONRCAL number changing back and forth between two hex numbers, as the digital circuits were bit switching. Even this slight change in the status of the ADAM would be monitored by the handheld display to provide information that ADAM was still communicating with the VDU.

Source voltages from the central processing unit (CPU) board, digital input/output (I/O), and A/D board also were continuously monitored by a strip chart recorder to determine if any of the boards had shut down. If the source voltage on the CPU, I/O, or A/D boards dropped to zero at any time during a test, it would have been identified on the strip chart. This board would then have been identified as the source of a manikin shut down. Similarly, if the source voltage on all the boards dropped to zero simultaneously, the voltage regulators and power supply circuits would have been identified as the source of manikin shut down. As it turned out, there were no board failures in any of the tests performed.

In an attempt to pinpoint the source of the shutdown, data was again collected during the second profile tests, Figure 2, as the viscera thermocouple temperatures exceeded 180°F. When data was about to be collected, the VDU was taken out of the display calibration mode and put into the data collection mode. The handheld terminal would prompt the user that ADAM was ready to collect data, the display verified that ADAM was still communicating with the VDU and was set to collect data. Next, the short to the start signal connection was removed and ADAM was to collect data. The Decommutator (Decom) system can be used to continuously monitor a single channel of ADAM data throughout a test. Frequently word number 28 was monitored because of the large hex change associated with it when ADAM received a start signal. Typically the hex number would be 197 and change to 139 after ADAM received a start signal, but when data were not collected, the hex display would become unreadable, as ADAM was not transmitting an actual hex number. The frame sync indicator light on the Decom would also flash meaning that the data being sent through the Decom was not coming in the proper frame size. When ADAM operated correctly, it would take one minute for the data to be sent to the Decom. When ADAM was not operating properly, the frame search indicator lamp would never light, meaning the Decom never saw an end data flag and continued to search for data in the proper frame format.

Because the frame search indicator lamp did not light, ADAM was not able to transmit data through the telemetry port correctly. Attempts were made to download any data ADAM might have collected internally, but no data could be downloaded. This meant that the data itself was collected, but neither the Decom nor the Data Retrieval and Storage System (DRASS) could interpret the data. When data collection was again attempted and ADAM was put into the data collection mode using the VDU, a "memory full" message was displayed on the VDU screen. Therefore the data had been sent and stored in ADAM's internal RAM, but when it was sent to the telemetry port and grouped into frames to be sent to the Decom or sent out the parallel port to the DRASS, the data was unrecognizable. Because the data was never able to be downloaded under these circumstances, it could not be determined whether the data stored in the RAM was good. It is known from the "memory full" message that ADAM did receive the start signal and collected some data.

Continuous monitoring of the system diagnostics using the VDU verified that ADAM was always able to communicate with the handheld terminal up to the time that data collection was attempted. If the temperature inside the viscera continued to rise after the telemetry port had shut down eventually ADAM would stop communicating with the VDU and the digital communication link to ADAM was lost, signifying that additional digital circuits had shut down. This seems to indicate that the first circuit to shut down from the heat inside the viscera was the telemetry port.

SENSORS AND DATA ACQUISITION SYSTEM

Introduction

The final aspect of this test program was to conduct a preliminary study of the affect of temperature on the manikin's sensors and the integrity of the data acquisition system. ADAM is a highly instrumented manikin that was designed to provide information about the position, velocity, acceleration, and forces experienced by all segments of the manikin. To achieve this, position potentiometers, load cells, torque sensors, and accelerometers are present in the manikin.

To determine if data degradation occurred, several manikin sensors were continuously monitored by a strip chart recorder to measure sensor drifts directly associated with the sensor itself. A load cell measuring a 50 lb static load, external to the chamber, was connected to one of ADAM's "extra" channels that was reserved for collecting seat and parachute data during ejection testing. This load cell, not exposed to the high ambient temperatures, would show whether ADAM's data acquisition system was altering the known external load cell input data. All other internal manikin sensors were operated normally and these data were compared to the sensors monitored by the strip chart recorder.

Potentiometers

Position potentiometers are present throughout ADAM's arms and legs to measure the angle of each joint throughout an ejection test. Because of the extreme length of these tests, the data collected only represents a single point in time for each test. Except for the internal temperature probe, all of the manikin sensors should remain constant during the entire static test. Initial test data, data collected during the test, and final test data was directly compared to discern drifts among all data sets. Additionally, the potentiometer monitoring the left knee flexion channel on the strip chart recorder was continuously checked to determine drifts in the sensor output signal.

Data plots from two typical potentiometers, the lumbar pitch and the right elbow flexion, will be discussed further. Figure 31 shows a typical output plot for the lumbar pitch channel. The large spikes in Figure 31 are due to an anomaly in the data acquisition and will be discussed in more detail in the data acquisition section. The small spikes are present due to the analog signal hovering at a bit switching value. The amplitude of the bit switching represents the resolution of the channel. Figure 32 represents the initial and final data collected on the lumbar pitch channel for Test 9. The amplitudes are identical and consistent as expected. This was typical of all of the monitored channels. Figure 33 represents what occurred on several channels at various random times. The first plot is the

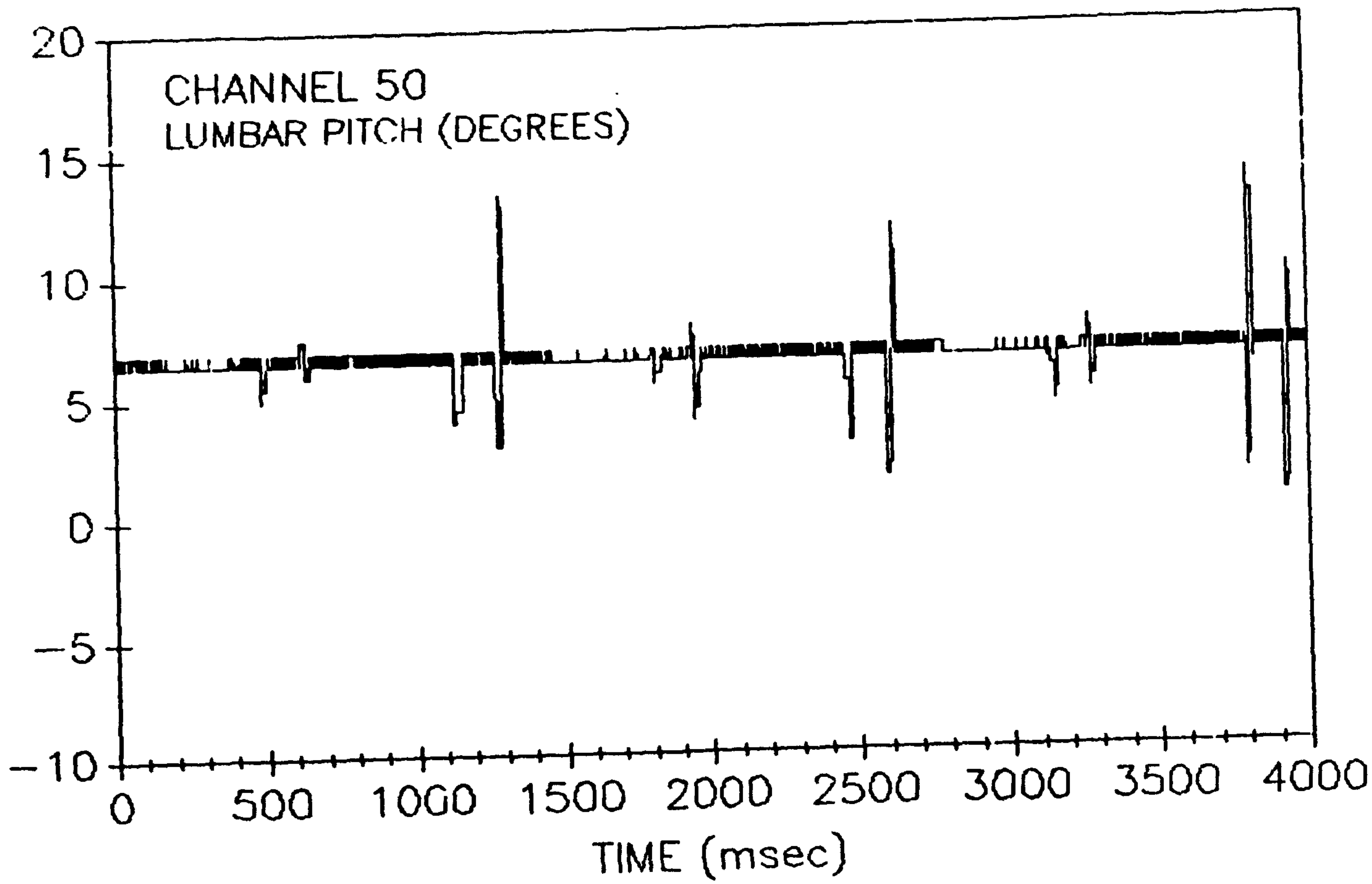

Figure 31 - Typical Potentiometer Output Plot

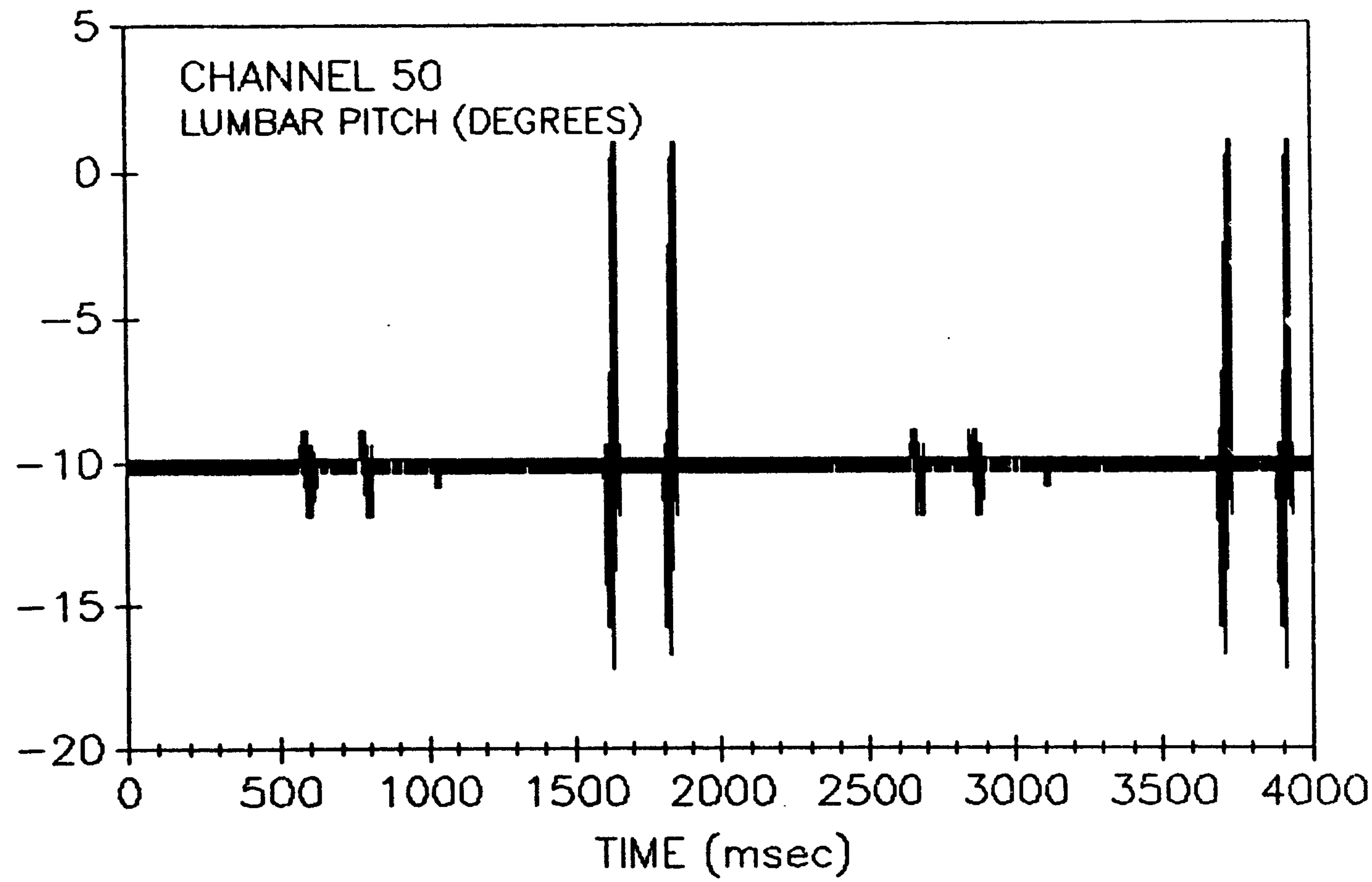

Figure 32 - Lumbar Pitch Showing No Sensor Drift (1 of 2)

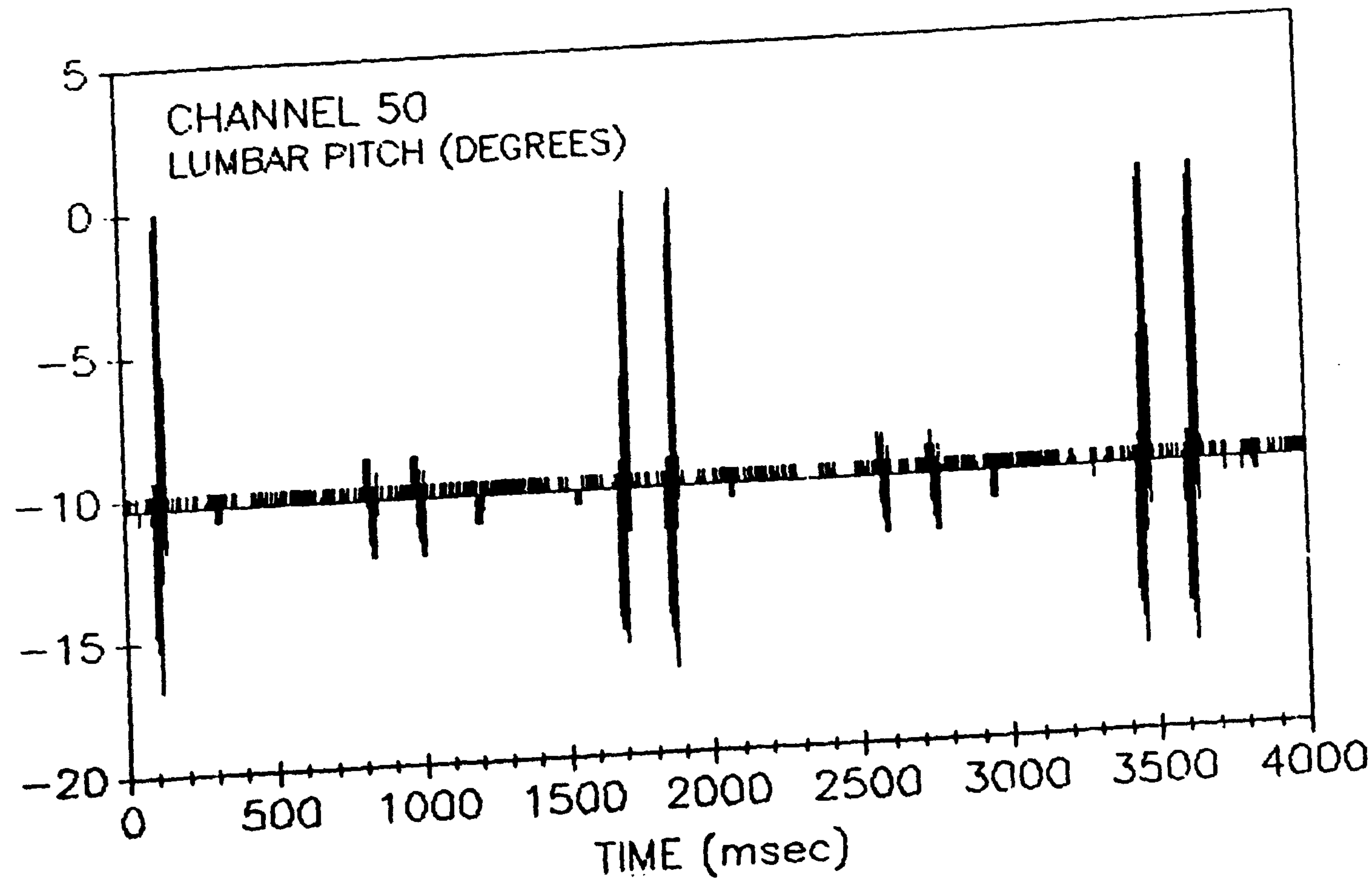

Figure 32 - Lumbar Pitch Showing No Sensor Drift
(2 of 2)

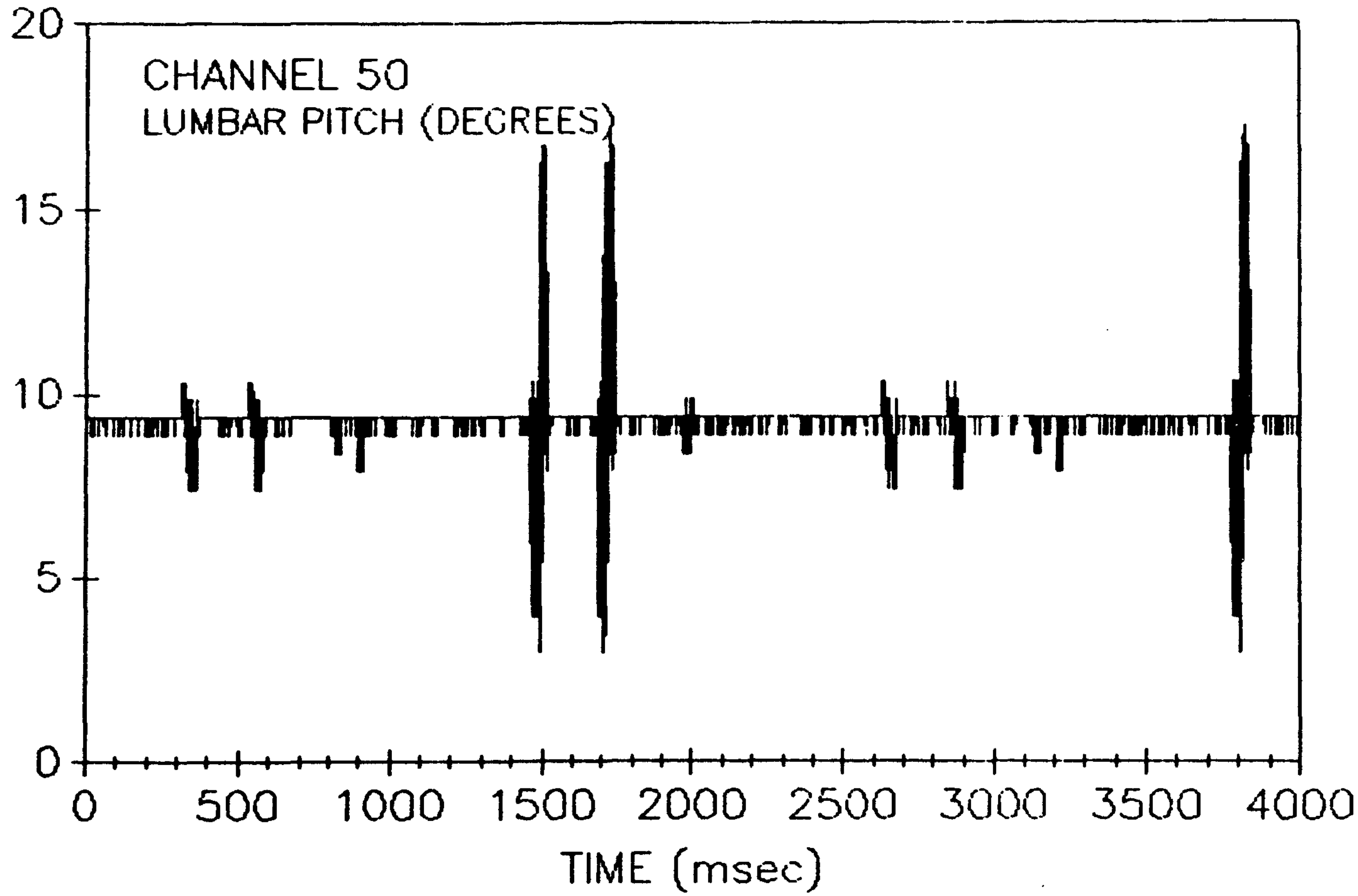

Figure 33 - Lumbar Pitch Showing Drift and Erratic Response (1 of 2)

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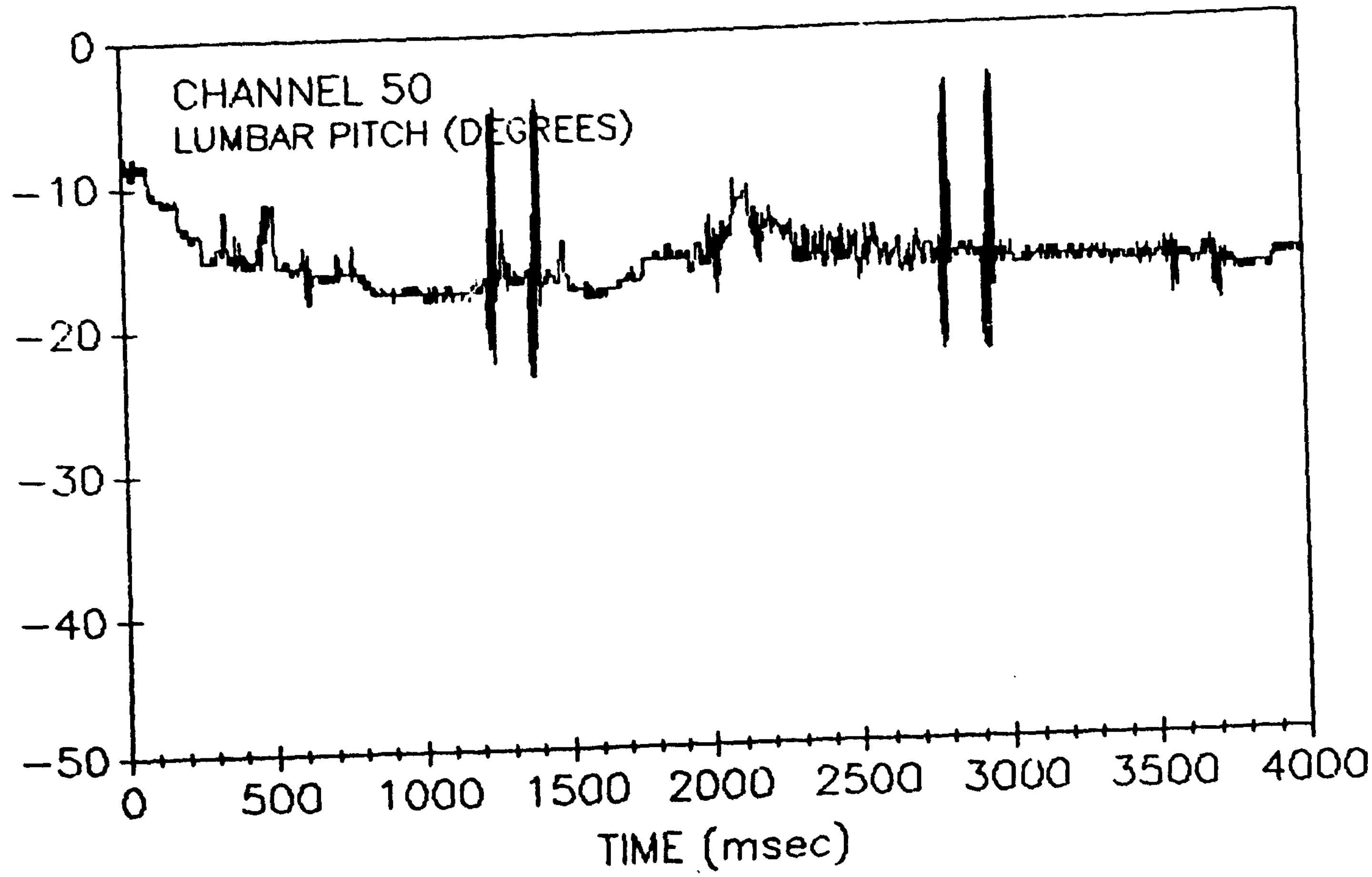

Figure 33 - Lumba[illegible] [illegible]tch Showing Drift and Erratic Response
(2 of 2)

initial data for Test 7. The second plot represents data that was collected as the viscera temperature reached 180°F on the viscera thermocouples. The data for the lumber pitch is changing during the data collection, but Figure 34 shows the right elbow flexion channel for the exact same data dump, which is constant as expected. Therefore the heat of the chamber was affecting the output of the lumbar pitch sensor.

In Test 7, exact isolation of the manikin shutdown temperature was being concluded. After the data in Figures 33 and 34 was taken, the memory was not erased until new data collection had been attempted. As soon as the DRASS had downloaded the previous data to the computer, a period of about 10 minutes, ADAM was given another start signal, but it did not receive the start signal through the telemetry port. The data that had been collected earlier and left in the manikin was downloaded successfully. This data was processed and compared to the same data downloaded ten minutes earlier. Comparing the erratic plot of Figure 35 to the second plot of Figure 33, which had been downloaded just before, showed that the data was identical. This proved to be true for all manikin channels. This simple test showed that the data had not been corrupted during a partial manikin shutdown. The data remained available until the system was rebooted. This fact could prove quite useful following an ejection test. If ADAM was ejected when the viscera temperature was near the safe operational temperature threshold, and continued to heat as it lay in the hot sun following a test, the manikin could partially shut down before ground crews could cool the manikin. Probably in most cases the data could still be downloaded after the manikin had cooled down.

The three plots of Figure 36 represent what continued exposure to a high ambient temperature environment can do to the potentiometers. The plots show that the potentiometer drifted from -14° to -9.5° and back to -12.3°. Similar results were found from time-to-time on the left knee flexion channel, which was externally excited and continuously recorded on the strip chart. Because of the continuous monitoring, it was possible to view the response of the potentiometer throughout the entire test. Figure 37 shows a small scale drift during Test 8. The left knee flexion potentiometer displayed several large drifts caused by a loss of contact at the sensor. The Appendix documents a loss of contact in a wire connection for that channel that was external to the manikin, but still in the chamber. Both of these situations were the result of the thermal environment. Figure 38 shows the response.

Load Cells

Several load cells are present in ADAM. The most important one is the six-axis head/neck load cell mounted between the neck and base of the head. The strip chart recorder continuously monitored the neck 'Y' force channel. No noticeable drifts were apparent in this channel. Due to the limited number of channels

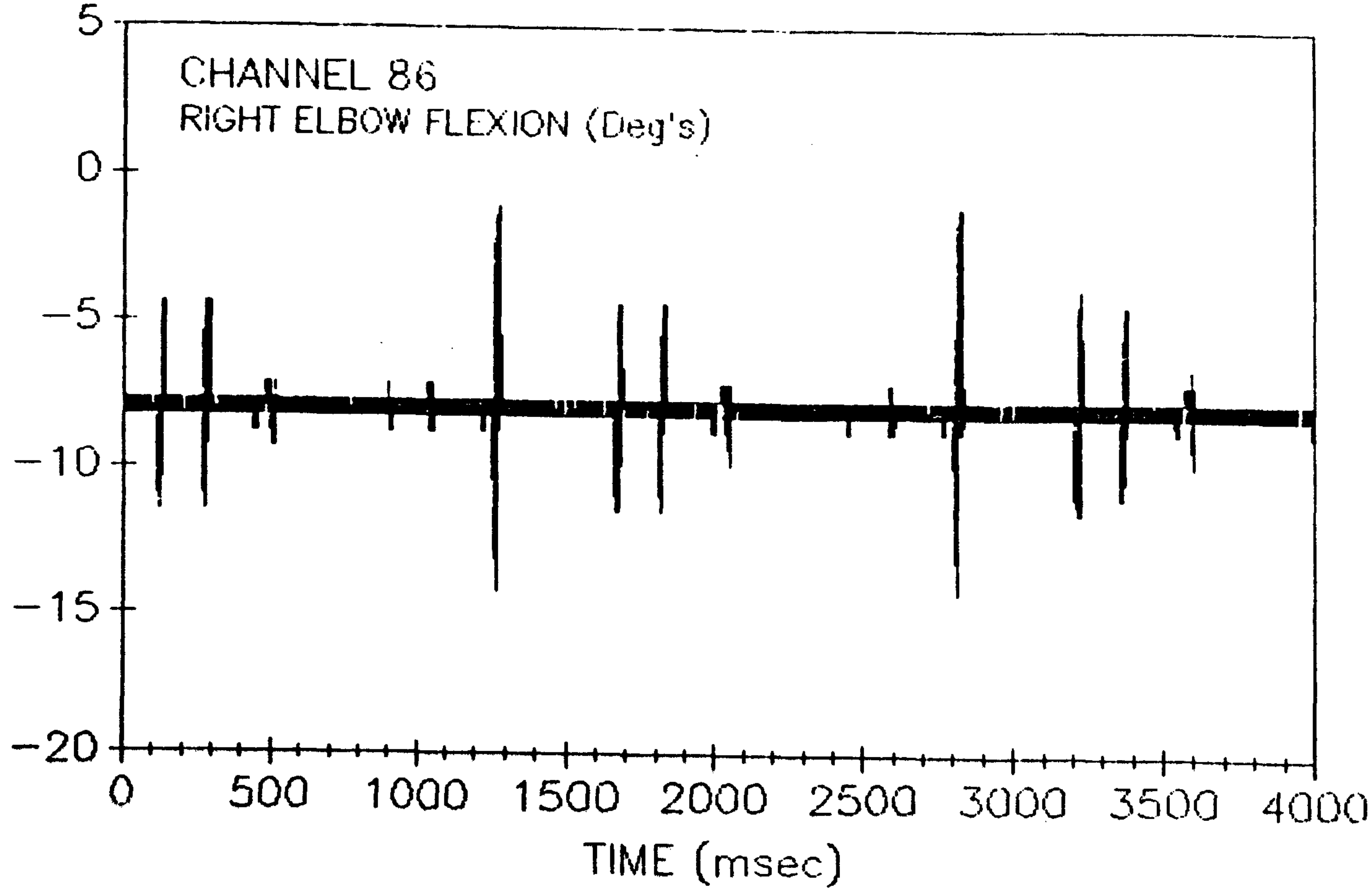

Figure 34 - Elbow Flexion Showing No Drift Compared to Lumbar Pitch

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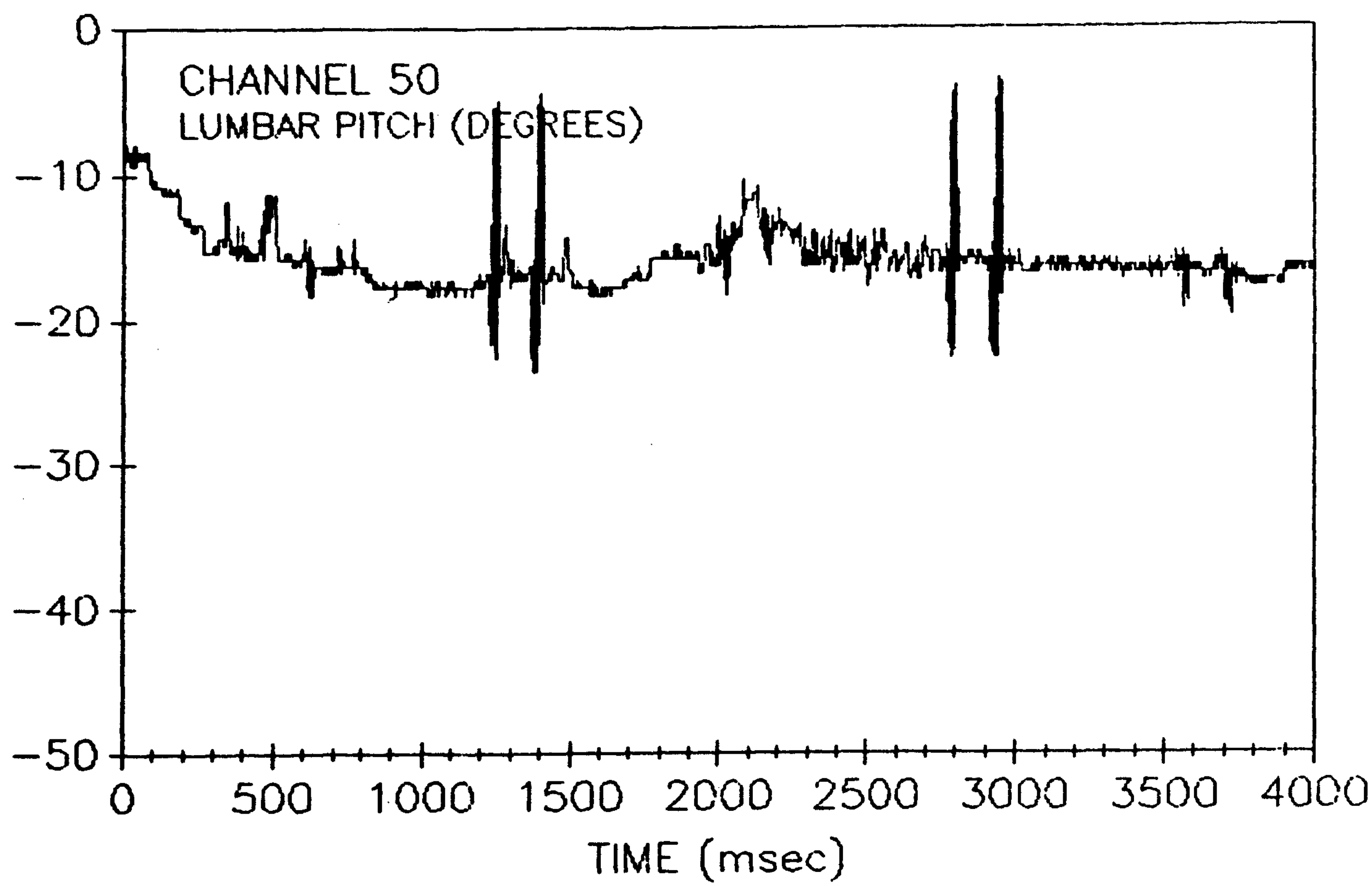

Figure 35 - Lumbar Pitch Showing No Corruption Due to RAM Data Storage

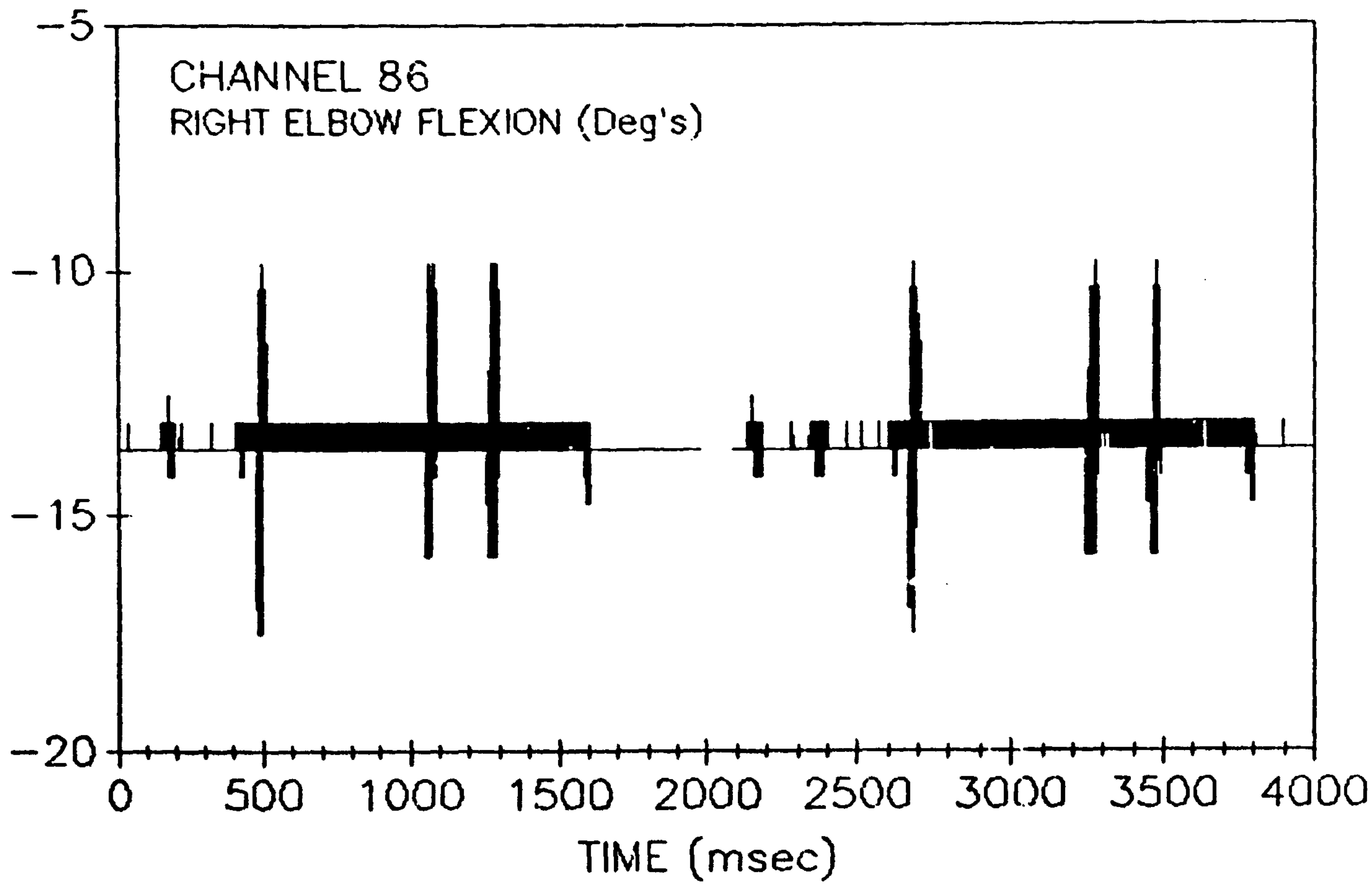

Figure 36 - Elbow Flexion Showing Sensor Drift
(1 of 3)

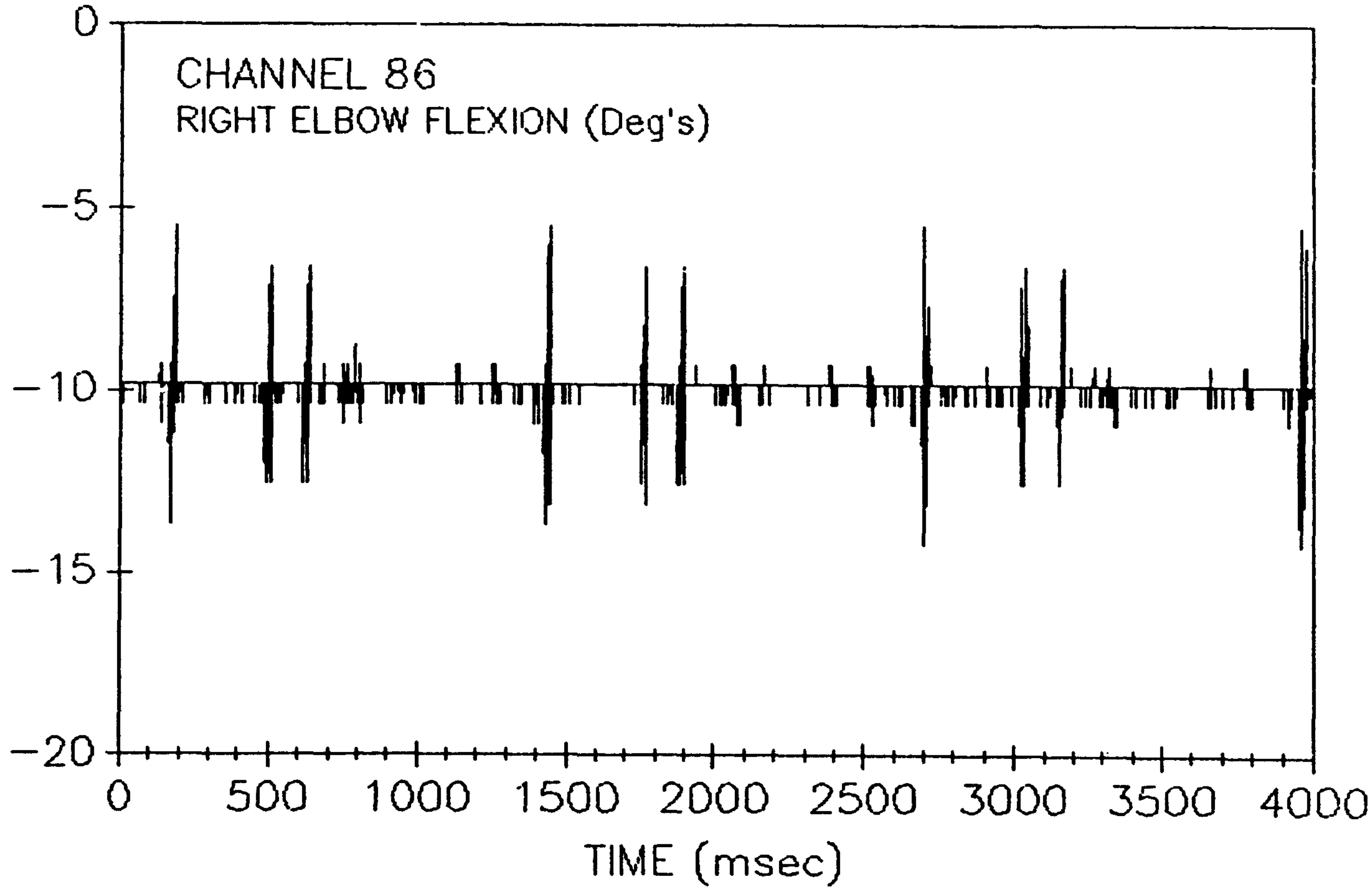

Figure 36 - Elbow Flexion Showing Sensor Drift
(2 of 3)

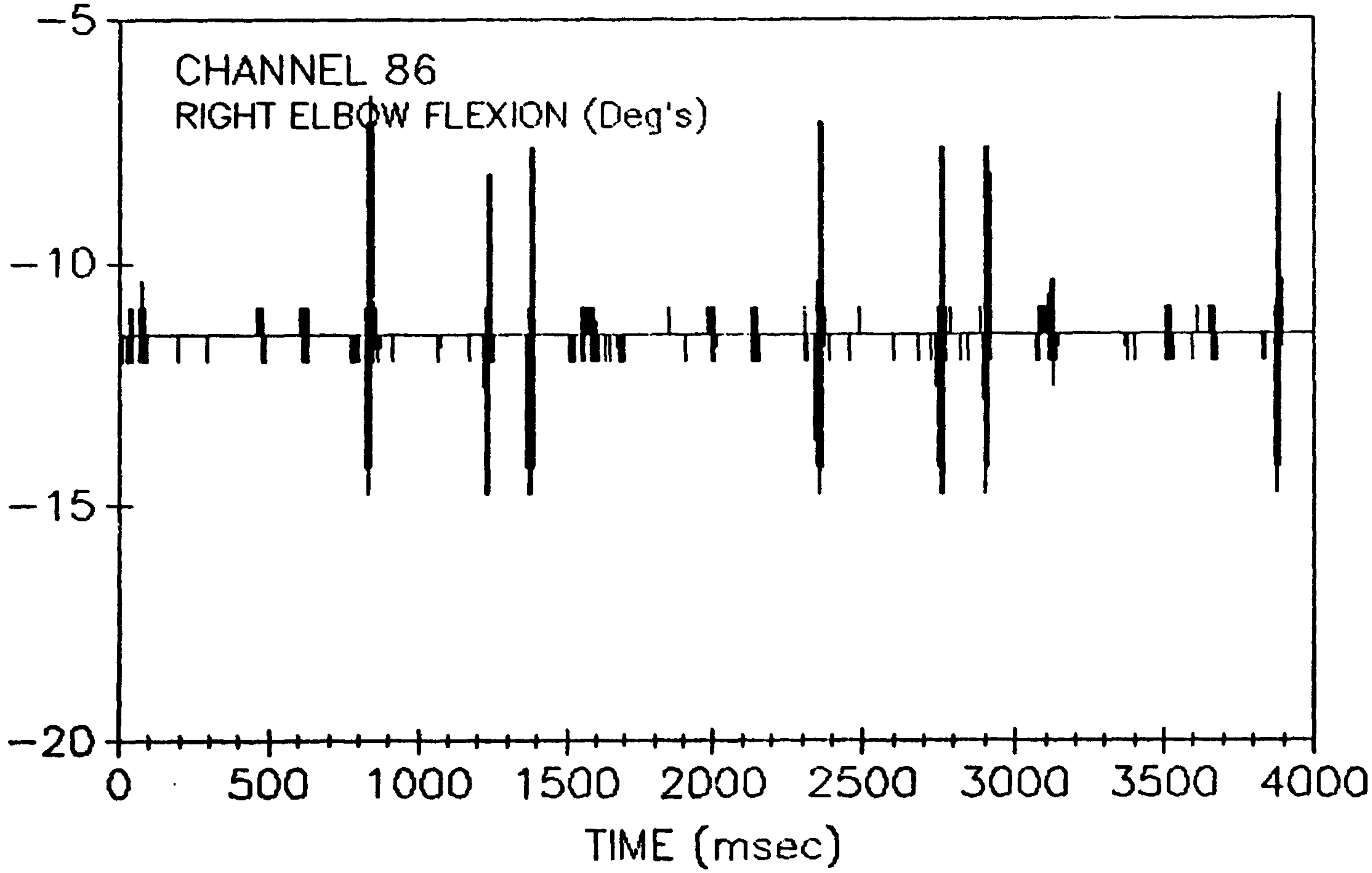

Figure 36 - Elbow Flexion Showing Sensor Drift
(3 of 3)

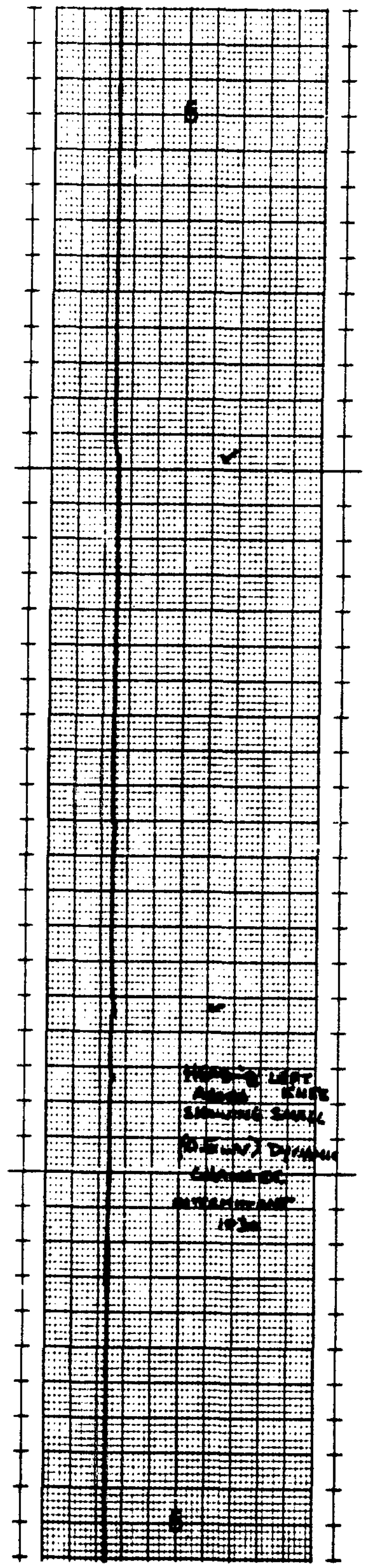

Figure 37 - Knee Flexion Strip Chart Showing Drift

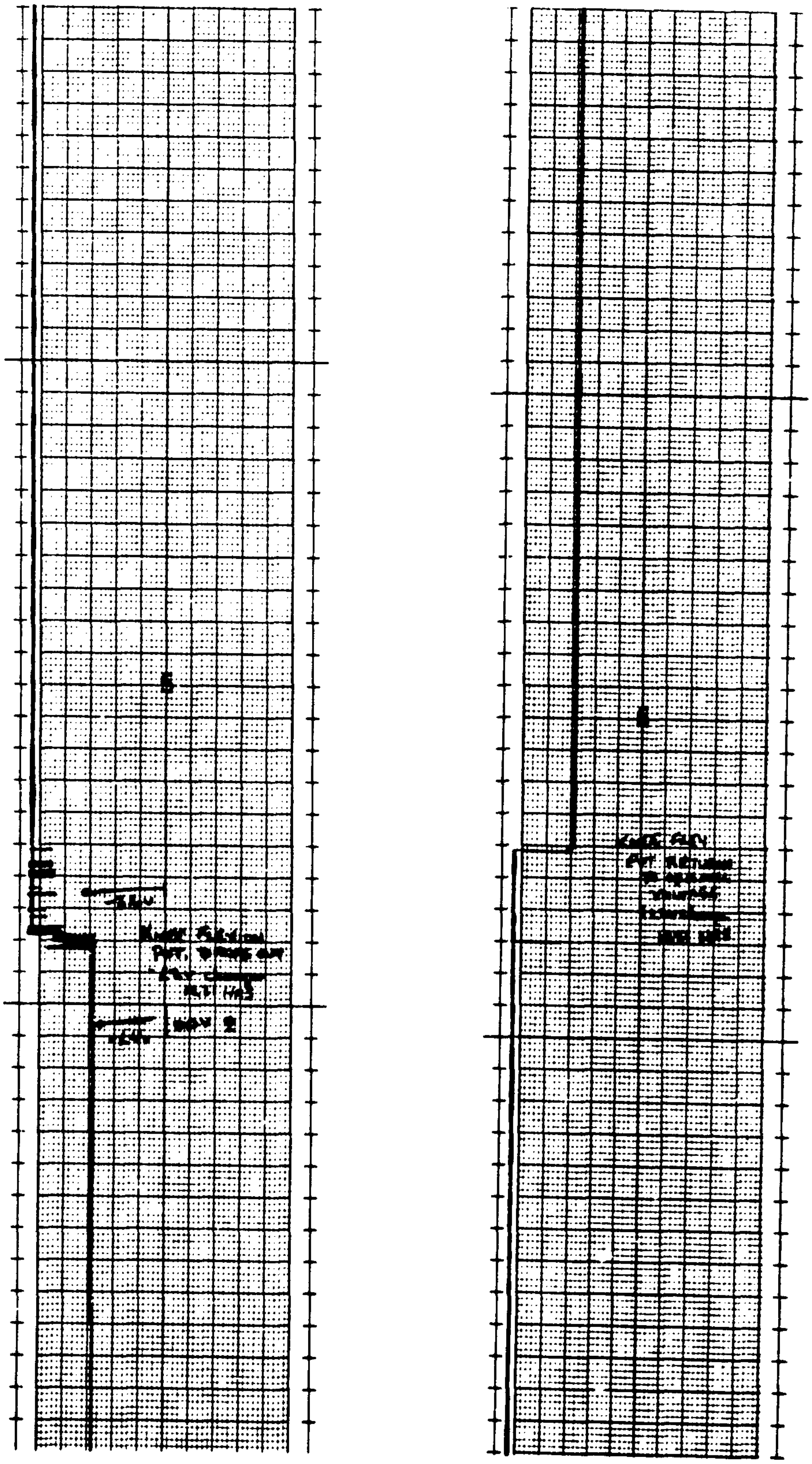

Figure 38 - Knee Flexion Strip Chart Showing Large Drift From Loss of Contact

that could be monitored on the strip chart recorder and the six-axis load cell being connected as a unit, monitoring a single head/neck load cell channel on the strip chart recorder meant none of the other five channels could be monitored by the ADAM data acquisition system. Based on the measured response from the neck 'Y' force channel, it is reasonable to assume that the entire load cell would function similarly.

The external load cell, mentioned previously, measured a 50 lb static weight and was located in the air conditioned control room. The load cell was connected to ADAM through the left parachute riser channel and the data collected on channel 47, see Figure 39. Exempt from the thermal environment of the test chamber the data shown on channel 47 should remain constant throughout the entire test program, unless the data acquisition system was introducing drifts in the data. Additional tests need to be conducted, but there are some noted irregularities in the external load cell data. Figure 40 shows a sudden change in the load cell reading during data collection. Beginning with test 10 to get an even more stable input signal to ADAM, the load cell was replaced with a voltage standard whose input voltage to ADAM nearly matched the output signal from the load cell with the weight attached. The load cell was then monitored by the strip chart recorder to determine any drifts by the sensor itself.

Figure 41 shows that even after the load cell was replaced by the voltage standard, there was still some drifting in the collected data during a test. The voltage standard remained constant. As for the load cell itself, it showed no drift in any of the remaining tests. Therefore, it is assumed that for all of the tests, those using the external load cell and those using the voltage standard, the input signal to channel 47 was constant. Any drift in the data would then be attributed to the data acquisition system.

Accelerometers

The accelerometers proved to be the most dynamic of the manikin's sensors. Figure 42 shows the head 'Z' accelerometer, which was monitored by the strip chart recorder, displaying both small and large drifts in output signal. This plot is taken from test 7, but this phenomenon was observed in almost every test with this accelerometer. It appears that the thermal compensating resistors present in the accelerometer were not working properly.

The head 'X' and 'Y' accelerometers were connected to ADAM and Figure 43 shows that during Test 14, the 'Y' accelerometer did not drift, but it did not measure the correct value of 0 G, but -1 G. The chest (torso) accelerometer mounting block is mounted to the top of the viscera box. A thermocouple was mounted there and temperatures were measured to within 10°F of the thermocouple located inside of the viscera. Small thermal drifts were observed in nearly every accelerometer, but Figure 44 shows that

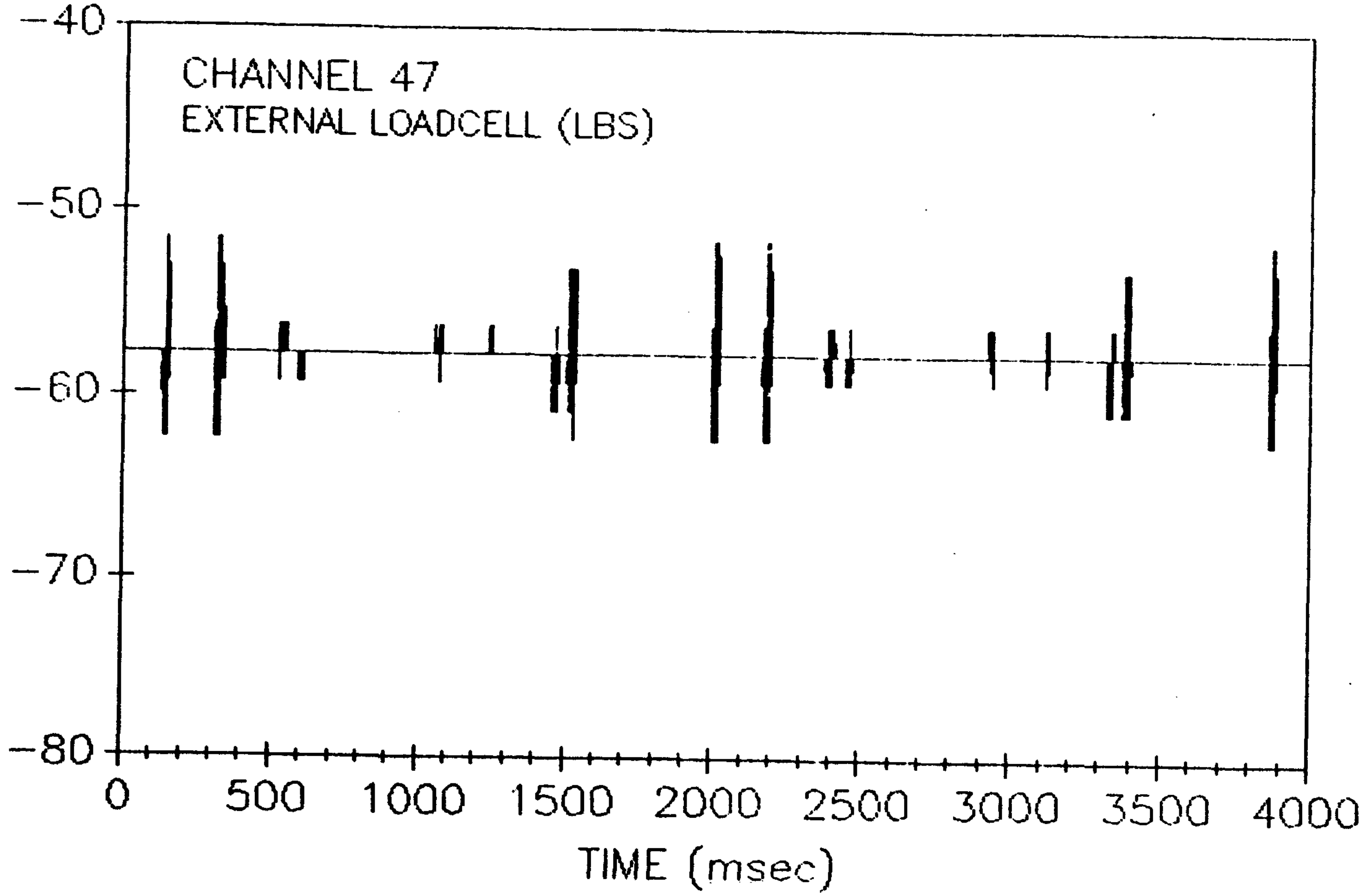

Figure 39 - External Load Cell Typical Plot

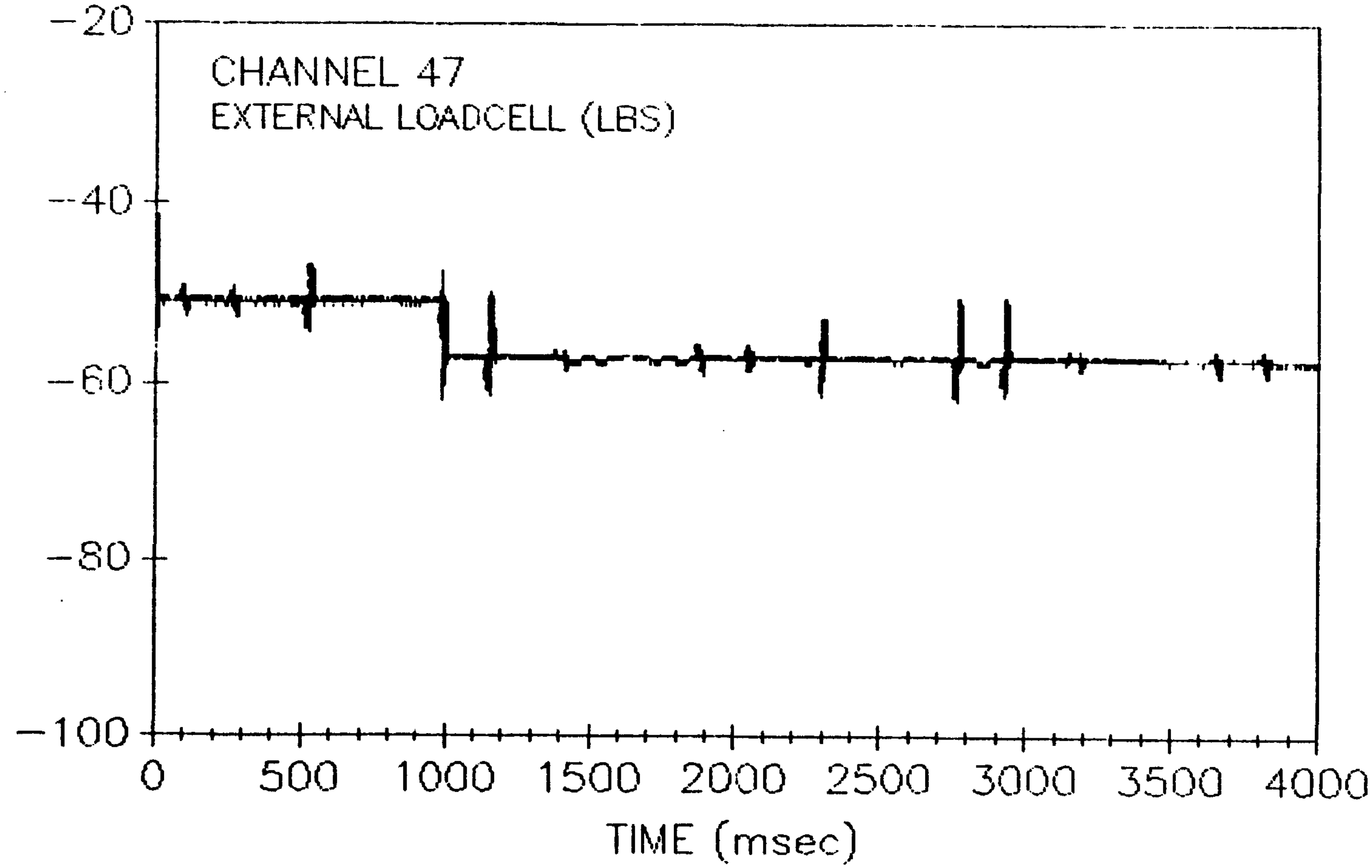

Figure 40 - External Load Cell Showing Dynamic Response

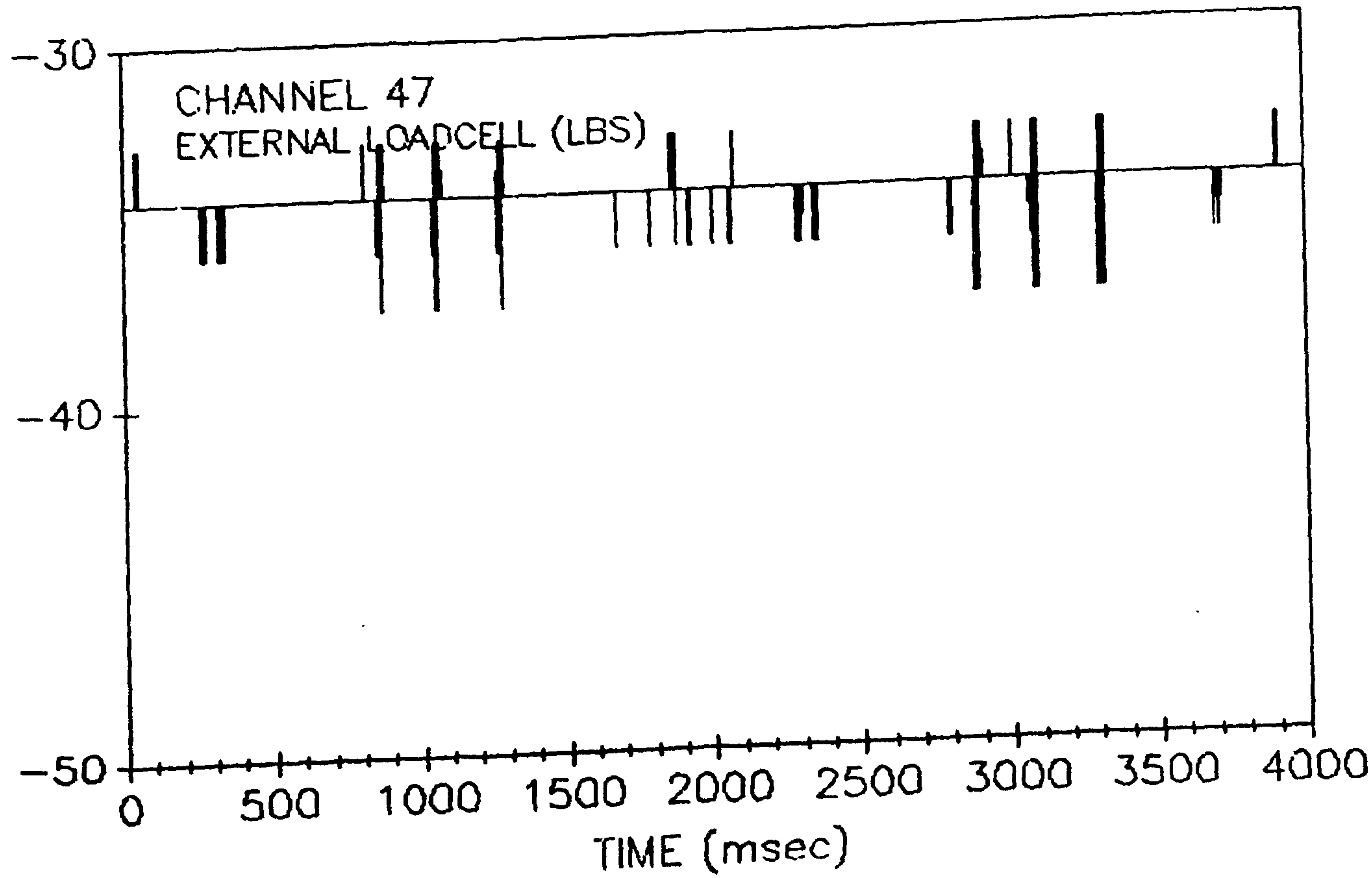

Figure 41 - Voltage Standard Representing External Load Cell Showing Drift (1 of 3)

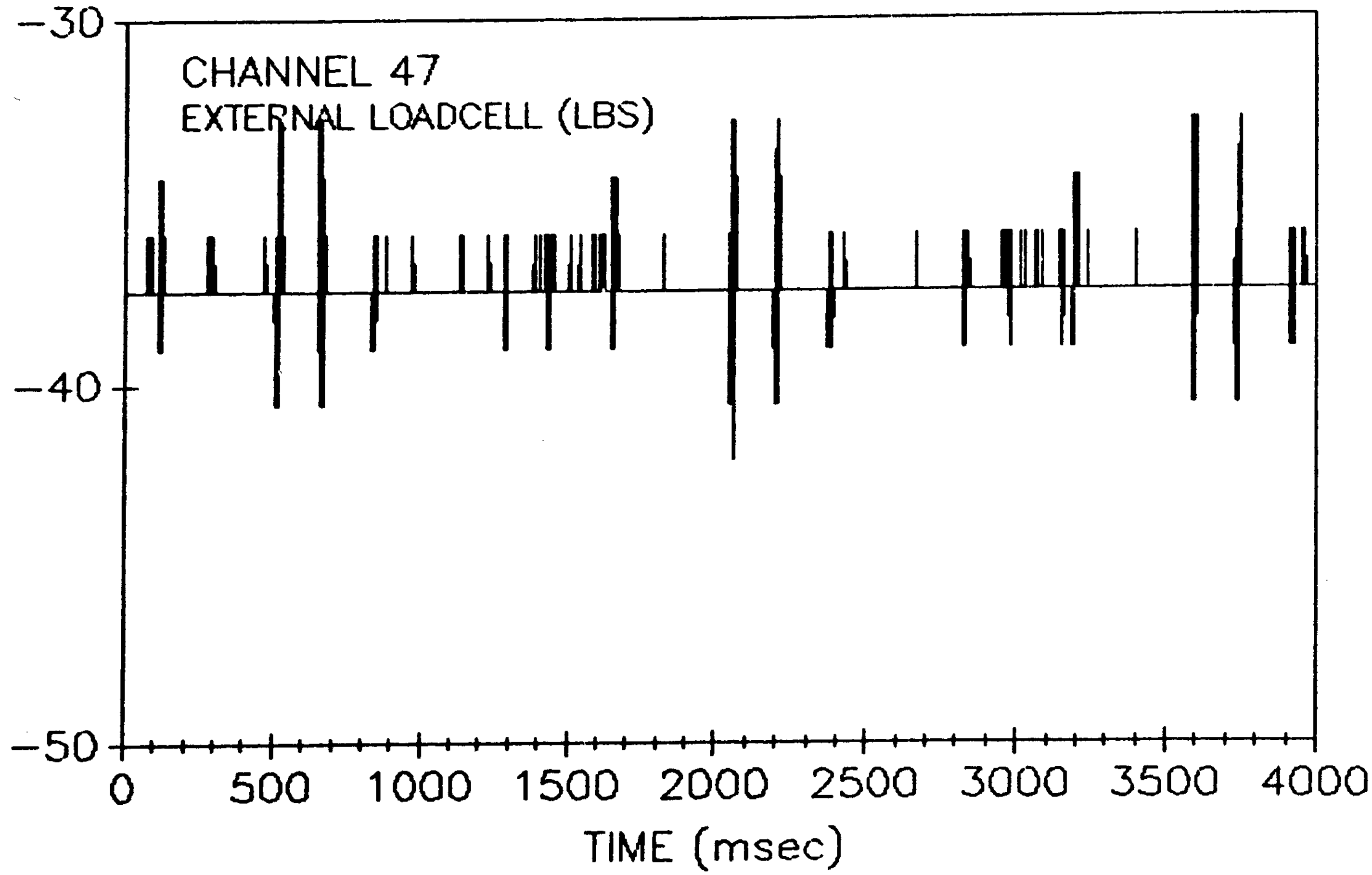

Figure 41 - Voltage Standard Representing External Load Cell Showing Drift (2 of 3)

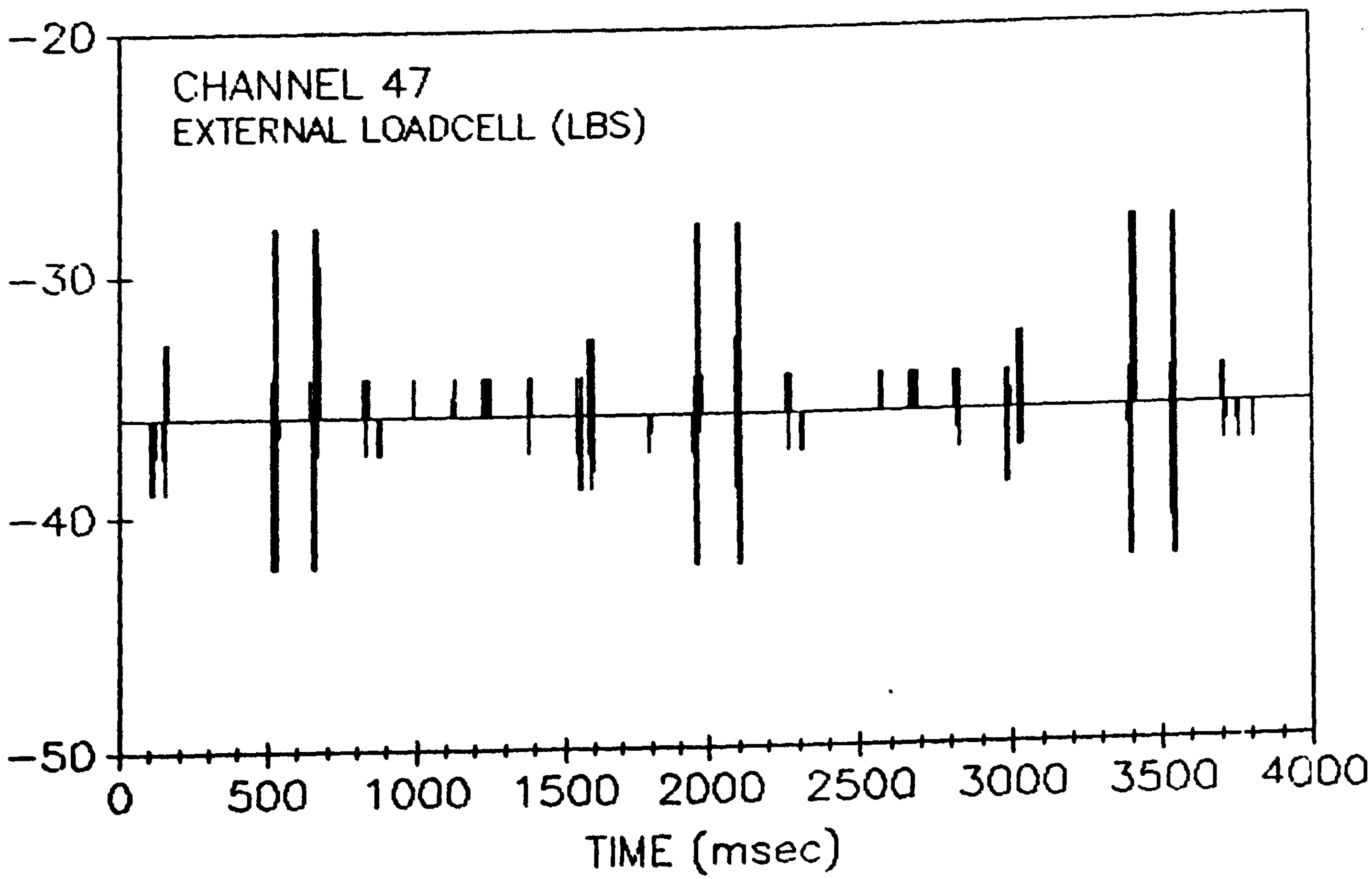

Figure 41 - Voltage Standard Representing External Load Cell Showing Drift (3 of 3)

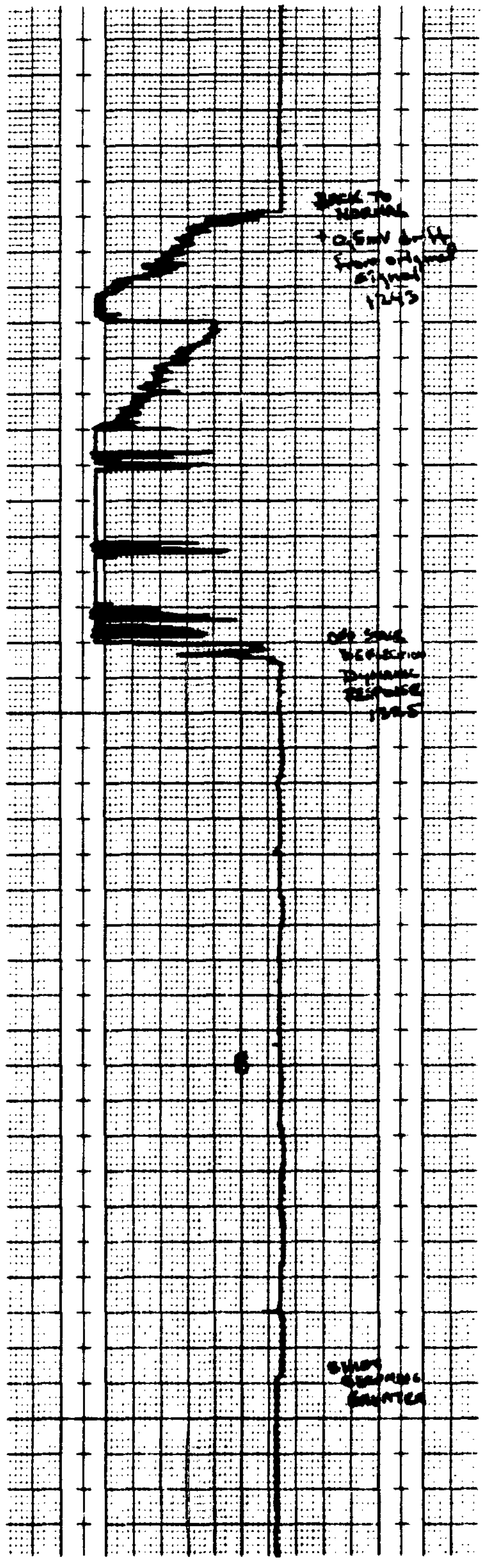

Figure 42 - Head 'Z' Accelerometer Showing Dynamic Response

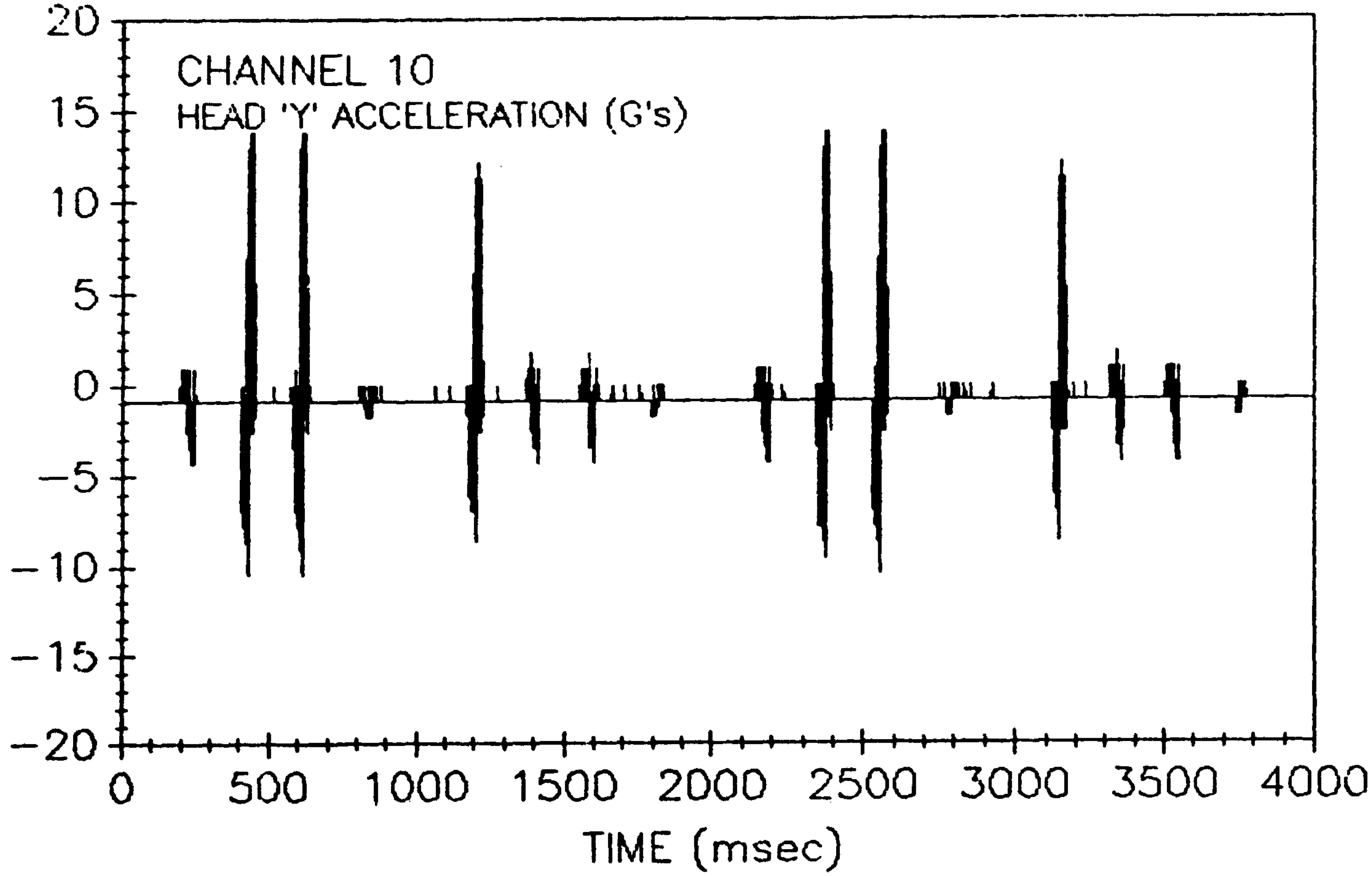

Figure 43 - Head 'Y' Accelerometer Showing No Sensor Drift (1 of 2)

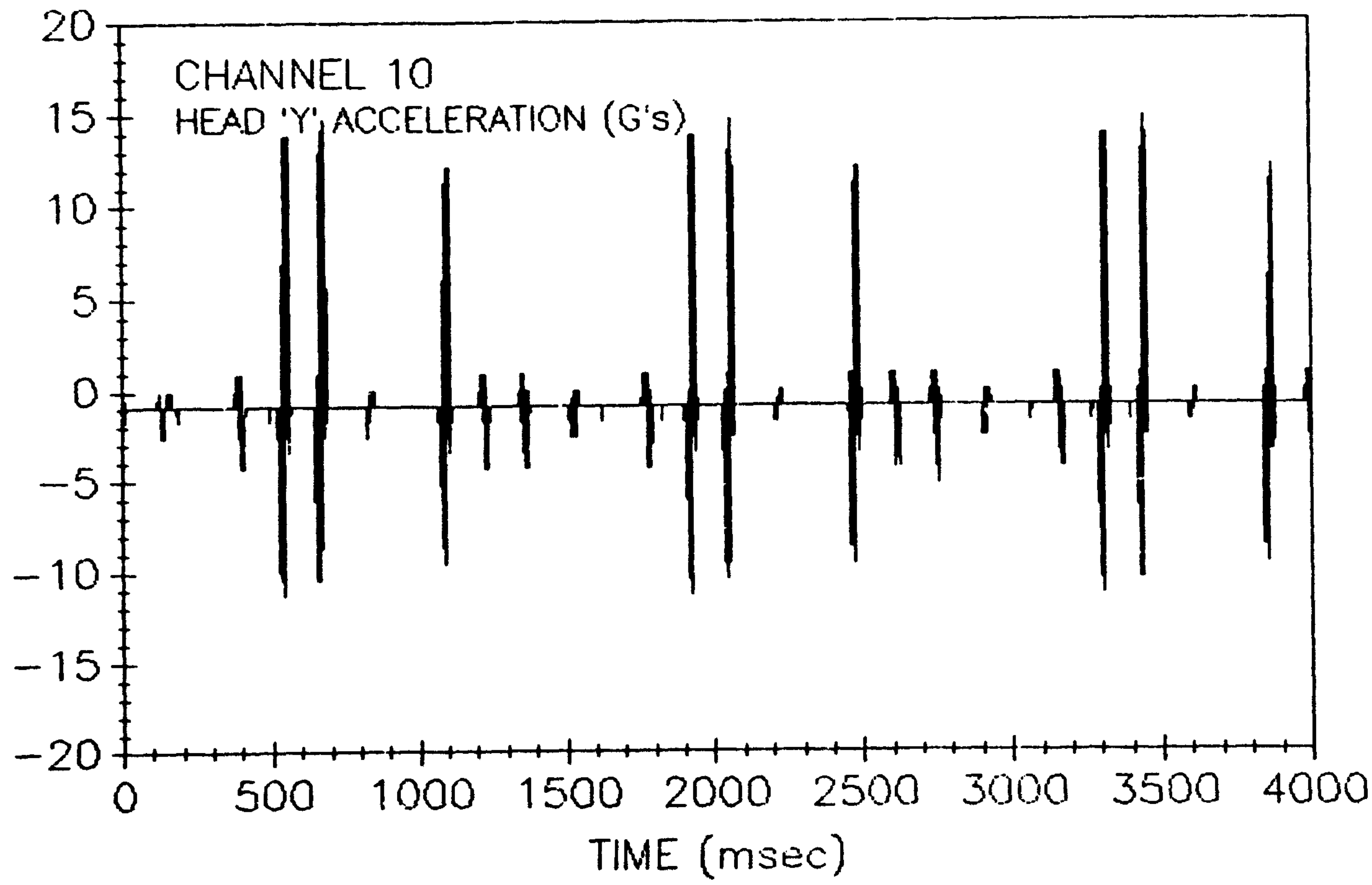

Figure 43 - Head 'Y' Accelerometer Showing No Sensor Drift
(2 of 2)

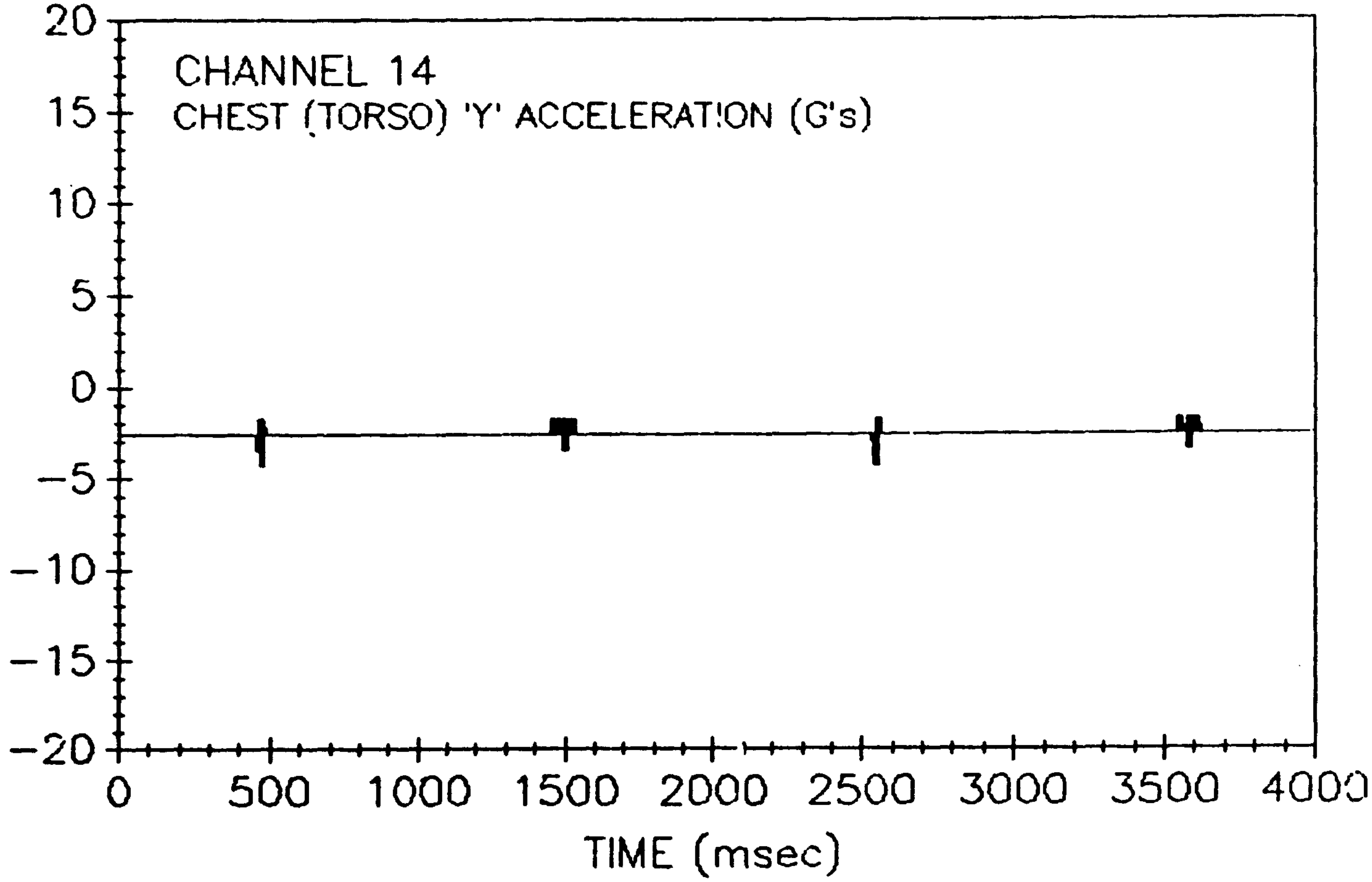

Figure 44 - Chest 'Y' Accelerometer Showing No Sensor Drift (1 of 2)

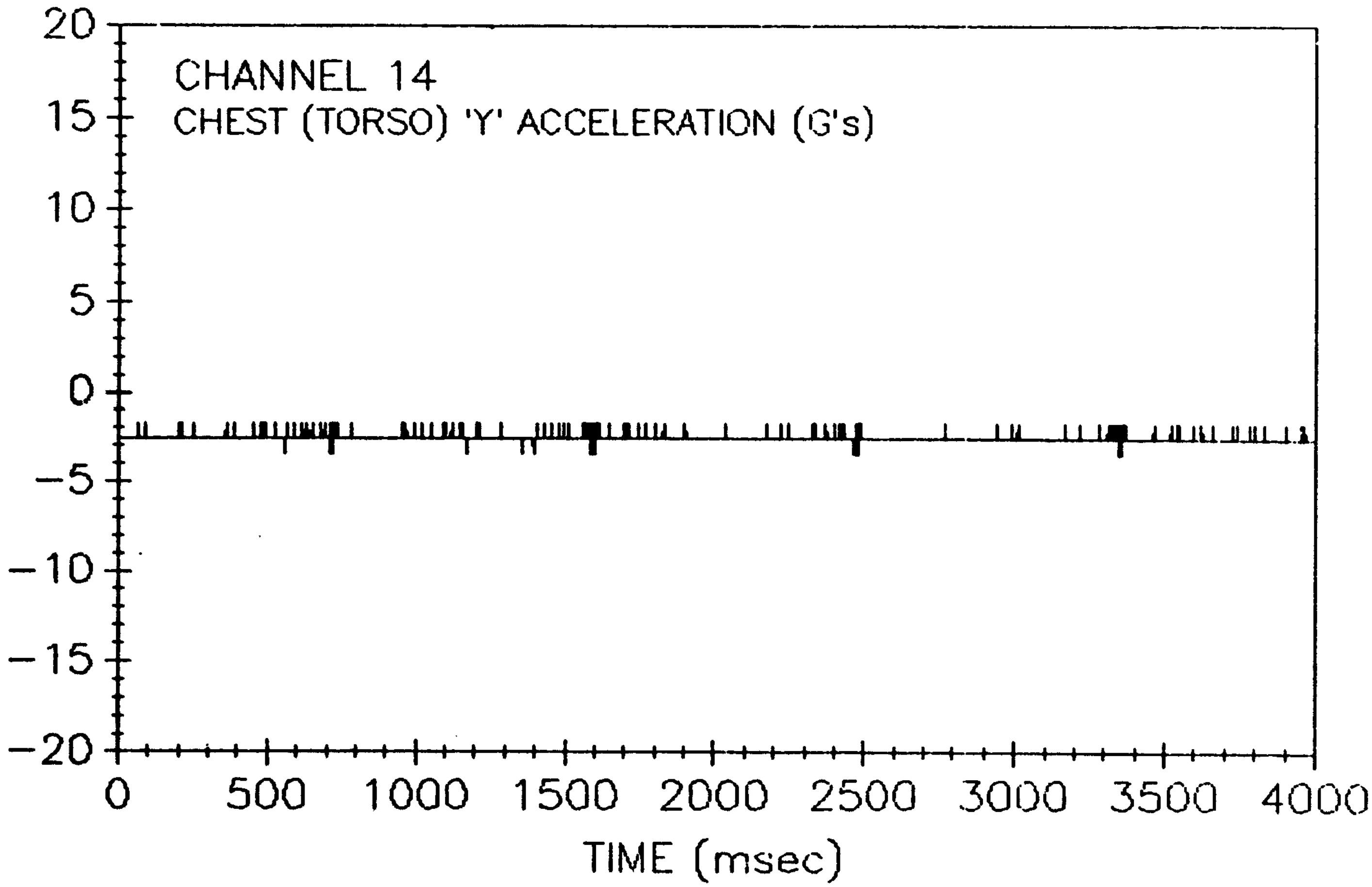

Figure 44 - Chest 'Y' Accelerometer Showing No Sensor Drift
(2 of 2)

at times even ones mounted above the viscera could hold a constant output signal, even though a drift apparently occurred in a previous test as the output signal is incorrect. It should read 0 G.

The chest 'Z' accelerometer proved to be the most erratic sensor. Figure 45 shows four plots from the consecutive tests, 2-5. At the beginning of the second test the accelerometer measured the correct value, +1 G. By the end of the test the reading had dropped to -10.5 G. The initial data from the next test showed that the accelerometer had not fully recovered from the effects of the heat in the previous test. Again the sensor drifted, but not as much. Since test 3 was a stand-by test the viscera was not as hot. But by the beginning of test 4, the sensor was again reading the correct value, only to drift again during the test. Again in test 5, the sensor drifted substantially.

Data Acquisition System

The test results indicate that the data acquisition system successfully operated beyond the ambient operating temperature of 160°F for an extended period of time. When the manikin did shut down, it was completely dependent on the internal viscera temperature. None of the manikin shut downs resulted in any failed components. Several sensors may have been heated beyond their limit and were no longer useful, but the data acquisition system was always recoverable after a shut down.

Drifts in the collected data can in some cases be positively linked to the sensors themselves and inconclusively to the data acquisition system in others. Overall the data acquisition system was very reliable. The high ambient temperatures to which ADAM was exposed to during the duration of this test program may have led to some internal drifting of the data acquisition system. Due to limitations of time and money it was not possible to investigate any further the cause of this internal drifting. Unaccountable drifting was most apparent in the parachute riser channel to which the external load cell and later the voltage standard were connected. Certainly the drifts shown in Figures 40 and 41 are related in some way to the data acquisition system.

The large spikes that are present in all of the figures showing plotted channel data were present in the initial data collected from the manikin prior to this test program, but due to test chamber scheduling limitations this anomaly was not resolved. Preliminary troubleshooting between tests indicate that the problem may lie in the synchronization of the internal clocks that control the data sampling. As the channels are sampled sequentially in a cycle, 1000 cycles/second, data is collected from every channel. If the clocks from the various circuits are not completely synchronized invalid data may be collected and

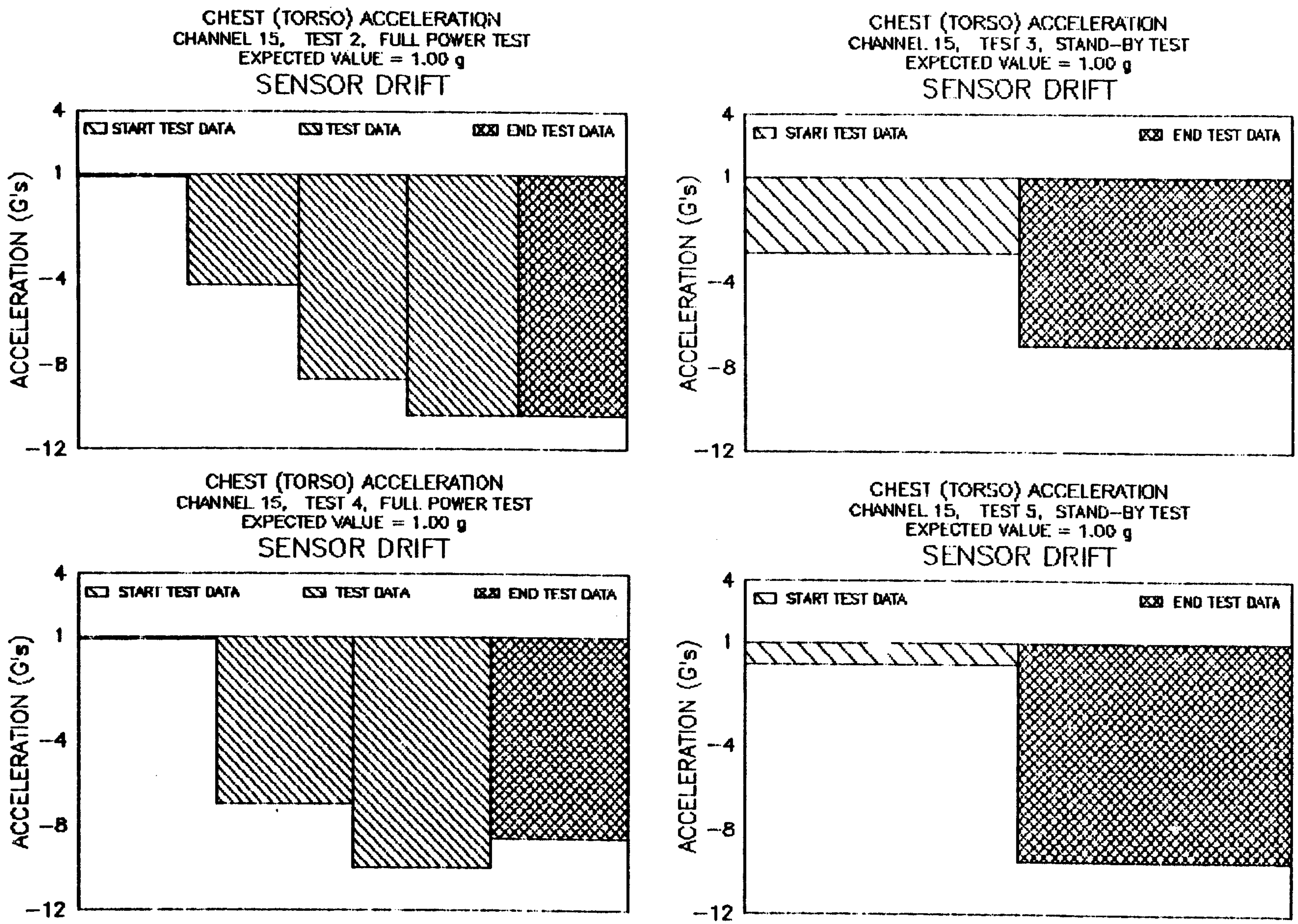

Figure 45 - Chest 'Z' Accelerometer Showing Sensor Drift in Tests 2-6

filtered. So, the spikes may represent garbage on the line and not the signal from the sensor. The apparent regularity of the spikes, see Figure 43, and their presence on every channel in every test support this hypothesis. These spikes, however, did not effect the validity of the data.

CONCLUSION

The tests described in this report were conducted to determine the ADAM's ability to operate in high temperature environments, determine safe operational temperature thresholds, and determine the need to provide conditioned air to the MASE sled cockpit for ejection testing at Holloman AFB, NM. The safe operational ambient temperature threshold was determined to be 130°F. corresponding to an internal temperature threshold of approximately 180°F. Since the stand-by mode status of the ADAM cannot provide the operator with the actual internal viscera temperature, another means of determining the temperature needs to be found. Tracking the local ambient temperature may be the most effective way to determine the operational capability of the ADAM. If the ambient temperature remains below 130°F, ADAM should function normally.

In normal operation the MASE sled cockpit does not reach a temperature of 130°F. It is therefore not necessary to introduce a conditioned air system into the sled. Although for extended pre-test work with the ADAM powered on, it may be advantageous to provide ADAM with some sort of air flow. This can be accomplished by either keeping the canopy open or using a flexible hose that vents an air flow through the viscera. This will ensure the internal temperature remains below the 180°F viscera temperature threshold.

The use of the lycra suit or flight suit will further restrict air flow around the manikin and cause the viscera temperature to increase. If both suits are worn the viscera temperature can climb an additional 12-17°F. In most testing environments ADAM will wear some sort of outer clothing material, so this is an important factor to consider.

Careful pre- and post-test calibrations should be performed on the ADAM's instrumentation prior to a test series. The effects of temperature were visible in the drifting of sensor data during a prolonged test. Although some of the sensors have built in temperature compensating resistors, they did not always perform properly.

If the ADAM does shut down, the cause of the problem will most likely be the telemetry port. If ADAM is cooled below the operational temperature threshold, ADAM should still be capable of downloading any collected data.

Overall these tests provided a great deal of insight into the operation of the ADAM manikin in severe environments. The ADAM proved to be very reliable and resilient throughout the test program. The similarity of manikin shut downs led to the determination of a safe operating temperature range and the prediction of when and how the ADAM would shut down.

APPENDIX

TEST-BY-TEST EVENT DESCRIPTION

Date: 12 April 1990, Thursday

Test Cell A Test 1
Test No. 01

Time	
0830	ADAM powered up given start signal and a dump taken. Processed Channel 47, the external loadcall to determine system integrity. Processed data was 1.56 lb for that channel with the 50 lb wt. Restart and dynamically changed the weight on the loadcell. Jim had forgotten to hang the weight the processed channel reads - 57 lb, excitation lines remeasured, but only measuring drift. The five extra thermocouples were placed around ADAM as prescribed in the drawing. A sheet was placed between ADAM and the chair, hopefully he won't slide off.
1010	Chamber closed and ADAM off completely, soaking chamber to 70°F. Running profile for Cell A Test 1, Test Type 1; 130°F ramp.
1030	Test Profile Started. ADAM, Chart reader, Chamber all checkout okay.
1430	Test Profile Met, 130°F, 70% RH, no problems, ADAM okay, no noticeable sensor drift.
1530	Some sensor drift noticed on Channel 6 - Head 'Z' acceleration. Started @ 1500 hrs. ADAM okay. Also noticed leg must have moved slightly @ 1200 hrs see Channel 5.
1727	ADAM powered up fully, given start signal and collected data, ADAM okay. Test appears to be successful - refer to strip chart Test No. 01 and processed channel data.

Date: 13 April 1990, Friday

Test Cell B Test 1
Test No. 02

Time	
0745	Pretest checkout shows no problems with ADAM. Thermocouple on back of ADAM's head came a little loose from humidity, fixed. No condensation noticed on him. Sheet between him and chair dry. Baseline data collected from RAM, 0800 okay. ADAM cooling and preparing chamber for test.
0900	Mechanical Pretest completed (posttests Electrical and Mechanical waived). Chamber set to soak at 70°F.
0915	Test Profile started. Adam okay.
1035	Data collected. Analog section automatically shut down after data is transmitted (i.e., temperature probe drops to zero). VDU used to power up analog section again. okay
1315	Test Profile met, 130°F, 70% RH, no problems, ADAM okay. VISCERA temperature TC at 163.4°F. Data collected. okay. The thermocouple plots have been interrupted while Mike changes the paper.
1445	Data collected. No problems, ADAM okay, VISCERA temperature TC at 173.1°F.
1620	Data collected. No problems, ADAM okay, VISCERA temperature TC at 177.8°F. End test. Test appears successful.

Date: 16 April 1990

Test Cell A Test 2
Test No. 03

Time	
0750	Pretest checkout shows no problems with ADAM. A few joint torques a little loose, waived but will keep monitoring. Used "hanging post" for pretest mechanical test and to put on flight suit. Not the best system but workable.
0945	Test profile began 0945. ADAM and chamber okay.
1030	ADAM okay VISCERA temperature at 108°F.
1115	Download completed and data processed on WRDC Z-248 computer. Okay. ADAM okay, VISCERA 112°F.
1400	Profile reached 1345, ADAM okay, VISCERA temperature 147.8°F. Leg must have had large movement around 1230. Voltage now off scale (1.1v change). Noise also present at time of change.
1515	Leg position appears to have gone back to original position. Very uncertain about this. 1.1v change back to original voltage at 1436 hrs. ADAM okay, VISCERA temperature 155.8°F.
1605	ADAM okay, VISCERA 159.1°F. Comparing the results of this test to that of test No.: 01. Same profile, same ADAM status, no flight suit. VISCERA, VISCERA and chest skin temperatures all running 8-10°F hotter in this test with the flight suit on. This is bad news especially for the profile coming up tomorrow at 130°F with full power and both suits!
1643	ADAM fully powered, data collected, ADAM okay, VISCERA temperature 162.8°F. End test.
1705	ADAM turned off. ADAM okay, VISCERA temperature 173.6°F. Cooling now. Another good one!

Date: 17 April 1990, Tuesday

Test Cell: B Test 2
Test No. 04

Time	
0755	Ran through Pretest Electrical checklist. Collected data, ADAM okay. ADAM turned off again for pretest Mechanical checklist. Both the lycra and flight suits will be worn.
0945	TEST START, ADAM okay, VISCERA 89.9°F. The lycra suit is a pain to put on! Flight suit not too bad. Seat closer to wall due to routing of cables, lost some length. Mike said airflow around him will not be affected. Data collected, ADAM okay.
1145	Data collected, ADAM okay, VISCERA 148.2°F.
1345	Data collected, ADAM okay, VISCERA 176.9°F. Profile Met, 130°F at 70% RH.
1535	ADAM collected data, but we were unable to download him to the Drass. Problem with ADAM VISCERA temperature 196.0°F. ADAM powered down to standby to cool slightly. Chamber continuing mission. Cooling ADAM for 5 minutes.
1555	Trying again. VISCERA temperature down to 190.6°F. ADAM will no longer communicate with the handheld. Putting back on standby and will stop chamber profile and cool. Will try to collect data from ADAM starting once the VISCERA temperature drops to 180°F and if unsuccessful, at 10°F increments until data is collected. Chamber cooling. Mission stopped (6:10 hrs).
1630	Attempted to collect data, system not responding, VISCERA at 180°F.
1650	Chamber cooled to 70°F. Mike will continue to decrease temperature to 50°F.
1700	Attempted to collect data, system not responding, VISCERA at 170°F.
1710	System turned off and back on again. Hardware reboot, VISCERA at 168°F. Collected data and downloaded successfully to Drass. End test.

Date: 18 April 1990, Wednesday | Test Cell: C | Test 1
Test No.: 05

Time	
0800	Electrical Pretest completed. Adam okay.
0845	Started Mechanical Pretest. <u>Thermocouple #13 (back of ADAM's head) moved to ADAM's top left corner of VISCERA</u> to give a better temperature profile. TC #15 still in top right corner of VISCERA. Will determine VISCERA gradient if present.
0915	Chamber closed and soaking at 70°F. Initial ADAM test data collected. Put back on standby.
0950	Test start, baseline data collected. Test start, 160°F, 80% RH profile. ADAM okay.
1250	Test profile met, 160°F. ADAM okay, VISCERA temperature TC #17 @ 156.2°F, TC #15 @ 155.6°F. Chamber TC #18 @ 155-156°F. The coolest T.C. is #17 VISCERA box ext.! On standby at 30°F/hr temperature profile. ADAM's VISCERA heating no faster than chamber. Question is How high and how fast will he go from here?
1350	Test profile has been held for 1 hour now. ADAM okay. Left VISCERA probe 172°F, right 178°F. VISCERA box 166.8°F. All other TC 157 and 158°F.
1520	It was noticed that thermocouple #16 came loose from the shoulder and is pointing behind ADAM in the free air stream. TC #16 reading 158°F. ADAM okay, VISCERA probes reading #13 @ 179.6°F, #15 @ 180.0°F. He might make this one.
1605	Just 45 minutes to go. ADAM okay, VISCERA #13 @ 180.3°F, #15 @ 182.5°F. Chamber 158.8°F
1645	Attempted to collect data, could not download. VISCERA @ 188°F. Turned system power off and on again. ADAM: computer part working, talking to handheld, but unsuccessful in downloading data. Stopped test at exactly 7 hours. Cooling chamber, ADAM off.
1700	VISCERA temperature #13 @ 176.4°F, #14 @ 180.0°F. Hard system reboot (power back on). ADAM collected and downloaded data. End test.

Date: 19 April 1990, Thursday | Test Cell: D | Test: 1
Test No.: 06

Time

0840 Mechanical Pretest completed with ADAM in the seat. We are running test 1 of cell D, fully powered, no suits. To get an earlier start, kept him the chair. Little impact on the checklist.
Electrical Pretest completed, ADAM okay and ready. Chamber soaking at 70°F. Running the 160°F, 80% RH profile.

0855 Test profile started. Collected data. ADAM okay, VISCERA @ 74.9°F, chamber @ 70°F.

1005 Chamber @ 99°F, ADAM okay. Large temperature gradient developing in VISCERA. TC #13 on LHS reading 112.8°F while TC #15 on RHS reading 131.6°F. Yesterday both were about the same (within 2°F) but ADAM on standby. Today full power.

1045 Chamber @ 121°F. ADAM VISCERA #17 @ 135.5°F and #15 @ 150.4°F. A 15°F gradient across the VISCERA box. Ext VISCERA TC #17 @ 131.2°F. ADAM okay.

1100 Collected data and downloaded. ADAM okay. Chamber @ 128°F, VISCERA #13 @ 143.1°F, and #15 @ 156.7°F.

1145 Chamber @ 149°F, VISCERA #13 @ 164.0°F, #15 @ 174.5°F. Collected and downloaded data. ADAM okay.

1155 Chamber @ 155°F, VISCERA #13 @ 169.9°F, #15 @ 180.4°F. Collected and downloaded data. ADAM okay.

1158 Mission profile met 160°F. VISCERA #15 @ 182.1°F.

1213 ADAM VISCERA #13 @ 176.9°F, #15 @ 187.1°F. Collected and downloaded data. ADAM okay.

1228 ADAM VISCERA #13 @ 179°F, #15 @ 192.0°F. Downloaded again the data collected at 1213 (had been stored) but would not collect new data. Software reboot: would not collect data. VISCERA #15 @ 193.6°F. Hardware reboot: would not collect data. #15 @ 194.1°F. Still not, so must be working. Problem appears to be with telemetry port systems.

1240 Test stopped, ADAM still won't collect data. End test.

Date: 23 April 1990, Monday

Test Cell: C Test 2
Test No.: 07

Time	
0910	Pretest electrical and mechanical checklists completed. ADAM okay and collected sample data. Blue Lycra suit put on. TC #17 moved from outside of VISCERA to chest accel block above VISCERA to determine how hot the mounting block gets during a test. This may help explain some of the noticed drift in channel data.
0945	Test start. Collected and downloaded data. ADAM okay.
1010	Mission Profile started, finally! ADAM okay 98.2°F, chamber 71°F.
1120	Chamber 101°F, ADAM 113°F, VISCERA #17 @ 105°F on accel block. ADAM okay. The accel block appears to heat with VISCERA and only stays 7°F cooler than the interior of the VISCERA!
1315	Mission Profile met. Chamber temperature @ 157°F. Amazingly VISCERA #13 @ 154.8°F, #15 @ 152.7°F, #17 @ 146.4°F, #16 @ 146.6°F. All internal TCs are at a lower temperature than chamber !! Lycra suit is insulating ADAM from the hotter exterior! Head Z accel setting very erratic.
1325	Head Z accel off left end of scale! <u>Very dynamic</u> response here!!
1345	Head Z accel finally straightened out, back to normal.
1415	Chamber @ 158°F, VISCERA #13 @ 167.9°F, #15, @ 167.0°F, and #17 @ 161.1°F accel block. ADAM appears okay.
1540	VISCERA temperature 182.3°F. Powered up to collect data. Will not collect data VISCERA @ 183.6°F. Software reboot didn't work. Hardware reboot didn't work either. ADAM turned off to cool to 180°F. Chamber still on.
1600	Power turned back on VISCERA #13 @ 177.1°F, #15 @ 180.1°F. Collected data. ADAM okay. Left on full power. Will attempt to download data @ 190°F.
1609	Put back on stand-by heating too quickly, 189.7°F. DRASS hasn't transferred to Zenith yet.
1615	Transferred data that was kept at 190.1°F, transferred at 187.4°F.
1620	Transferred data and kept VISCERA @ 190.4°F. ADAM okay, transfer okay. End test. This is the same data as TST7B.DAT.

Date: 25 April 1990, Wednesday

Test Cell: D Test 2
Test No. 08

Time

0840 Electrical and Mechanical Pretests completed and Data collected. ADAM okay. Because both suits are being worn, DRASS cable short after data collected, ADAM moved to allow enough slack in the cable, so it could be corrected. Weight also not corrected before data collection. Do not make direct comparison of joint positions to this first data set, because he was moved.

0855 Mission Profile started.

1100 Knee potentiometer has shown a slight twitching on the strip chart recorder. Check before next test. Possibly use jumper. It worked as a check after the last test. ADAM okay, VISCERA #13 @ 164.4°F, #15 @ 160.5°F, #17 @ 147.3°F, Chamber @ 131°F. TC #13 consistently hotter than #15 today!

1156 Mission Profile met. ADAM okay. Collected and downloaded data. VISCERA #13 @ 182.6°F, #15 @ 179.2°F.

1200 TC #8 registers open on ACUREX. Head Z accel on strip chart giving small intermittent dynamic signals. Shouldn't happen!

1205 VISCERA #13 @ 185.7°F. Attempted but failed to collect data. Software reboot worked. ADAM still talking with handheld, put on stand-by to cool. Will attempt data collection again at 180°F.

1225 ADAM VISCERA #13 @ 180.2°F, #15 @ 180.4°F. Powered up, would not collect data, powered down (stand-by). Mission stopped. Chamber cooling.

1250 Software reboot. VISCERA #13 @ 178.4°F, #15 @ 180.2°F. Word No. 28 on Decon usually 197 and changes to 139 when collecting. Now was 27 and changed to 11. Would not come back. No data collected.

1255 Hardware reboot. Attempted but couldn't collect data. All ADAM power turned off to cool.

1311 Full power start-up. Data collected and transferred. Post test Electronic Checklist performed to check Rcal/NonRcal values. The Acceleromates drifted 7-9 hex RCAL and 2-10 hex NonRcal. Knee and temperature okay. End Test.

Date: 27 April 1990, Friday

Cell: E Test: 1
Test No.: 09

Time	
0810	Mechanical Checklist started. Final ADAM instrumentation checkout by Jim. Putting all the screws back and the VISCERA back together. New profile today. Stand-by with just skins. 5 hr test.
0930	Final preparations completed along with both checklists. Data collected. ADAM okay, chamber cooling to 70°F.
0940	Mission Profile started. Chamber @ 72°F, VISCERA #13 @ 71.3°F, #15 @ 89.1°F. ADAM okay.
1440	Mission Profile met. Up to 160°F. Held 2 hrs and cooled back down to 70°F. ADAM okay.
1500	ADAM fully powered up. Collected and downloaded data. ADAM okay. Not exciting at all, but successful!

Date: 30 April 1990, Monday   Cell: E Test: 2
Test No.: 10

Time

0750 Starting manikin preparations. Mechanical checklist to begin shortly. The lower leg torques (+ and -) that were assumed bad were checked and proven bad. Because several plots show drifts in the external loadcell output, the loadcell has been disconnected from ADAM. In its place we are using a voltage standard power supply to input 4mV into ADAM, simulating the loadcell. If drifts in the data now occurs on this channel, it will be proven to be ADAM, because this power supply, as mentioned, is a voltage standard. The external loadcell will be excited by a powersupply and data recorded on the strip chart recorder. This will determine whether or not the loadcell is good or not. Switched with I/O Ch #13 (.025X1).

0845 Pretest mechanical checklist started by Greg. He noticed the lock washer at the Rt elbow is rusting, may be one of the originals, before the stainless steel ones. Greg is also replacing and repairing softstops that were waived for the last test. See pretest Mechanical Checklist for specifics.
Not all softstops replaced, Greg's glue does not seem to be holding. Only other glue like it is at Woods. Will have it for tomorrows test. Don't want to hold this up and lose another day.

1000 All test preparations done. Both checklists completed. Data collected and downloaded. ADAM okay.

1010 Mission profile started

1510 Mission profile completed. ADAM okay, looking good. We're waiting for VISCERA temperature to level off before we collect data.

1600 Collected and downloaded data. ADAM okay, VISCERA #13 very dynamic 2°F continuous. VISCERA temperature = 130°F. Successful test.

Date: 1 May 1990, Tuesday

Cell: F Test 1
Test No.: 11

Time

0850 Pretest checklists both underway. Noticed bottom seat of flight suit and ADAM slightly damp yet this morning.

0945 Both checklists completed, chamber soaking @ 70°F. ADAM collected and downloaded data. ADAM okay. Powered down to stand-by until start of test.

1000 Mission Profile started.

1130 160°F chamber temperature (156°F) met. Collected and downloaded data. ADAM okay, VISCERA #13 @ 159.6°F, #15 @ 171.3°F.

1330 Profile starting to come back down. Attempted but couldn't collect data. Chamber @ 159°F, ADAM #13 @ 175°F, #15 @ 196°F. Profile running, cooling chamber. ADAM still on full power, cooling very slowly.

1505 Mission Profile ended, chamber @ 70°F. Attempted but failed to collect data. Software reboot didn't work either. Hardware reboot did. Collected and downloaded data. VISCERA #13 @ 110°F, #15 @ 142°F. ADAM okay again. End test.

Date: 2 May 1990, Wednesday

Cell: F Test 2
Test No.: 12

Time	
0930	Both mechanical and electrical checklists have been completed. ADAM powered up and collected data. Now put on stand-by waiting for the test. ADAM okay.
1000	Mission Profile started. ADAM okay. TC #13 was moved farther down into VISCERA box.
1130	Collected and downloaded data. ADAM okay. Chamber just reached 160°F. VISCERA #13 @ 168.5°F, #15 @ 163°F.
1330	Attempted to collect data, could not. Chamber back to 70°F. Profile over. VISCERA @ 210°F.
1510	ADAM fully off, try to cool him. Not cooling with power on.
1533	VISCERA @ 177°F. Powered up, collected and downloaded data. ADAM okay. End test.

Date: 3 May 1990, Thursday

Cell: G Test 1
Test No.: 13

Time	
0930	Both electrical and mechanical pretest checklists started. Greg regluing softstops.
1000	Chamber soaking at 70°F. Both checklists are complete. ADAM on stand-by. ADAM okay. Profile to start soon.
1010	Mission Profile started. Two complete cycles scheduled (6 hrs).
1605	Collected and downloaded data. ADAM okay, VISCERA = 130°F, chamber 80°F. End test!

Date: 4 May 1990, Friday

Cell: G Test 2
Test No.: 14

Time	
0920	Both checklists are done. ADAM okay. The chamber is soaking @ 70°F. All is well.
0958	Mission Profile started. ADAM okay. Collected and downloaded data.
1600	Mission Profile ended. Collected and downloaded data. ADAM okay, VISCERA #15 @ 145°F. Heated to 152°F when fully powered, now cooling. End test.

Date: 7 May 1990, Monday

Cell: H Test 1
Test No.: 15

Time	
0825	Pretest mechanical checklist started.
0915	ADAM ready. Pretest electrical checklist started.
0945	Mission Profile started. Collected and downloaded data. ADAM okay.
1110	Knee has begun a very dynamic response. It could be the connector, this was the problem before.
1145	One cycle complete. Chamber @ 70 °F. Collected and downloaded data. ADAM okay, VISCERA #13 @ 116.7 °F, #15 @ 148.6 °F.
1545	Mission Profile ended. Collected and downloaded data. ADAM okay, VISCERA #15 @ 156 °F. End test.

Date: 8 May 1990, Tuesday

Cell: H Test 2
Test No.: 16

Time	
0830	Pretest mechanical checklist started by Greg. This is the final test!
0955	Mission Profile started. Both checklists completed. Collected and downloaded data. ADAM okay.
1300	First cycle just completed. Collected and downloaded data. VISCERA #13 @ 179.5°F, #15 @ 173.3°F. ADAM okay.
1455	Collected data. Not downloaded. VISCERA #13 @ 183°F, #15 @ 181°F. ADAM okay.
1424	Second peak met in Mission Profile. Attempted but could not collect data. VISCERA #13 @ 189.1°F, #15 @ 186.3°F.
1555	Mission Profile ended. Attempted but could not collect data. VISCERA #13 @ 198.4°F, #15 @ 194.1°F. ADAM turned off and cooling.
1610	ADAM powered back up. VISCERA #13 @ 179.9°F, #15 @ 177.4°F. Collected and downloaded data. Posttest electrical checklist completed. ADAM okay. End test. End series.

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